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SCIENCE CONSPECTUS

VOL. VI 1916 No. 1

THE HORSE AND HIS PROGENITORS

SINGULARLY COMPLETE ANCESTRAL RECORDS SHOW HOW CLIMATIC CHANGES HAVE EVOLVED THE HORSE FROM ITS EARLIEST FOUR-TOED ANCESTOR

BY W. D. MATTHEW

THERE are several reasons why the evolution of the horse is of peculiar interest. First, because as a domestic animal it is so familiar to all of us and has played so large a part in the history of our own race, in the progress of civilization. Second, because it is one of the most marvellously perfect and beautiful illustrations of animal mechanism. It is one of the swiftest of large animals, specially adapted for rapid movement over long distances, and peculiarly fitted in every detail of its structure for its particular food, habits and environment. Third, because the geological record of its evolution is exceptionally complete. Fossil horses or rather stages in the ancestry of the horse are found in the Tertiary formations of the western states as far back as the beginning of the Eocene. They present a long series of successive stages through which it can be traced back to small and primitive beginnings, little removed from that common ancestral stock to which the various kinds of hoofed and clawed animals trace their origin. Most of these stages in the ancestry of the horse are now known from numerous specimens and more or less complete skeletons of each, so that we can observe in detail the progressive modifications of structure in every bone and tooth, and reconstruct pretty accurately the form and proportions of the body.

The Skeleton of the Horse.—If we compare the skeleton of a horse with that of a man, it is easy to see that with all the wide differences in proportions the fundamental plan is the same in both. The bones correspond throughout; their relations to each other, the characteristic form, muscular attachments and processes, are mostly identical. There are wide contrasts in proportions, however, especially in head and limbs. The head of the man is extremely short, and mostly brain-case. The head of the horse is extremely long, and mostly face and jaws. The horse is long-necked and deep-chested; the man is short-necked and wide-chested. The limbs of the horse are powerful, compactly built, limited in their movement to a fore and aft direction; the limbs of the man are long, slender, loose-jointed. But it is in the feet that the contrast is greatest. The five digits of the human hand and foot are in the horse reduced to a single digit greatly lengthened out, the nails converted into broad heavy hoofs to support the animal's weight. Of the inner and outer digit, first and fifth, no trace is seen; and of the second and fourth digit all that remains is the pair of slender, pointed splint-bones which lie pressed close to the main central digit or cannon-

bone. Thus the horse is quite accurately said to walk upon the tip of its middle finger-nail; the so-called knee of the fore-leg really corresponds to the wrist of man and the hock joint to the ankle; while the true knee-joint of the hind-leg and the elbow of the fore-leg are caught up into the flank, so that they hardly appear to be joints in the free limb.

The joints of ankle, wrist and feet are in man of the shallow cup-and-ball type which allows of free movement in any direction. In the horse they are all converted into hinge-joints more or less deeply grooved—a much stronger joint, but permitting of only fore-and-aft motion.

The teeth in man are a comparatively small and simple mechanism adapted to biting off and crushing soft food. In the horse they constitute a large complex and elaborate machine for cropping and thoroughly grinding the hard wiry grasses that form its natural food.

As a domestic animal the horse is of course found in all parts of the world; it is completely cosmopolitan. Through selective breeding by man various domestic races have been evolved, adapted to different purposes, ranging in size from the Shetland pony to the great Percheron draught horse, and with considerable variation in proportion as well. Broadly speaking the breeds fall into three groups —the Arabs and race-horses, the draught horses, and the ponies. In all the different domestic breeds the structure of skull, of teeth, of feet or other characteristic parts is almost identical; the differences are in size, proportions, color and markings of skin, amount of hair and so forth.

Wild horses are almost unknown today. The so-called wild horses found in various unsettled countries are mostly domestic stock escaped from restraint; they are feral, not true wild animals. There is, however, a small horse found in the deserts of central Asia, believed to be a truly wild species, and known as Przewalsky's horse.

The *asses and zebras*, while they differ in color, in the callosities of the legs and other surface characters from the horse, are closely allied and by most writers all are included in the single genus *Equus*. Setting aside subspecies and varieties there are two very distinct species of asses, the so-called Asiatic wild ass kiang, or onager, *Equus hemionus*, and the true wild ass of northern Africa, *Equus asinus*. Of the zebras there are, besides the quagga, now extinct, three distinct living species, each with a number of varieties. These are the Grèvy, Burchell and Mountain zebra. Besides differences in length and shape of head they are easily distinguished by the color pattern, especially on the rump. In the Grèvy. the narrow vertical stripes on flank and rump are characteristic. In the Burchell species there are instead broad oblique stripes extending quite across the rump, and in continuous series with the leg bars. The third species of zebra is the Mountain zebra *Equus zebra*, distinguished by the continuance of the vertical body striping in a narrow strip along the middle of the rump, with broad oblique stripes below. The face is noticeably shorter.

The zebras inhabit central and south Africa; the true wild ass northeast Africa, the kiangs Persia, northwest India and parts of central Asia, while the Przewalsky horse is found further to the northeast. This distribution of the surviving species of wild horses is but a small remnant of their widespread distribution during the Pleistocene, the latest geologic epoch. Numerous species of wild horses then inhabited the various parts of Europe, Asia, Africa, North and South America, wherever in these continents the climate and environment were suitable. These are all referred to the genus *Equus* and differ very little in skeleton character from the domestic horse, some being practically indistinguishable. The best known fossil species in this country is *Equus scotti*.

In South America, in addition to two or three species of *Equus* in the Pleistocene, there were other horses of the genera *Hippidium* and *Onohippidium*, one-toed like *Equus* but with shorter legs, teeth of different pattern, and some peculiarities in the nasal bones.

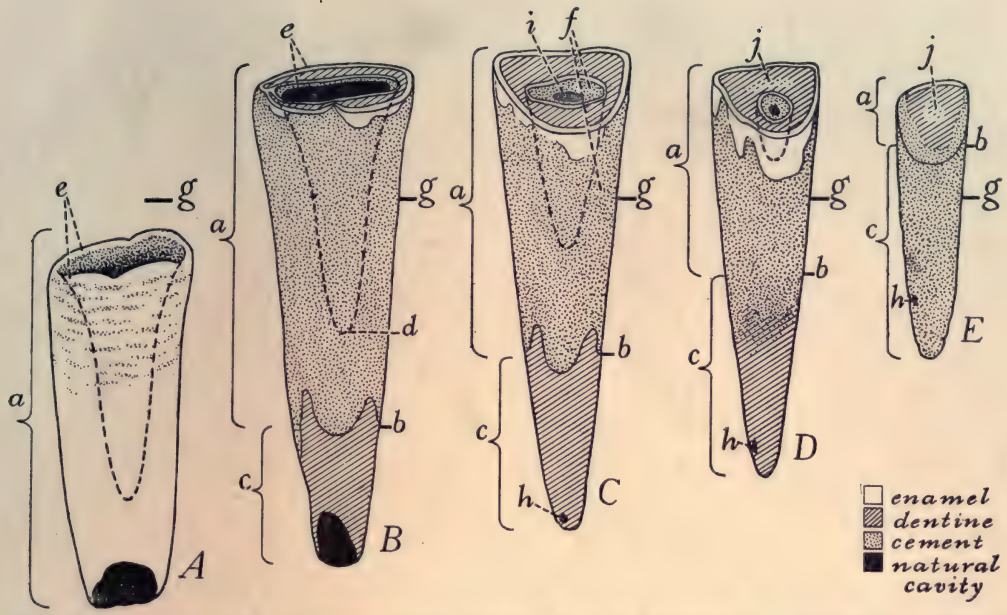

FIG. 31. Incisor teeth of a permanent set (i.[1]) showing wear and movement. Inner view. Natural size.

A. Tooth of a colt 2 years old before it has erupted. e, folded edge of enamel, unworn.

B. Tooth of horse 4 years old. a, crown; b, base of crown; c, incompleted root; d, bottom of cul-de-sac; e, worn edges of enamel; g, gum line.

C. Tooth of horse 12 years old. c, root fully grown; f, internal and external cement; h, nerve foramen; i, natural cavity in cement.

D. Tooth of horse 17 years old. j, "dental star."

E. Tooth of horse 33 years old.

All these wild horses of the new world became extinct before the coming of the white men. Most of them apparently had disappeared before the close of the Glacial Epoch. In the Old World most of the wild species likewise became extinct, but some survive in the modern asses and zebras, and others were the progenitors of the domestic horse. The origin of the various breeds has been traced by different authors sometimes to one, sometimes to three or more species corresponding to the three chief modern breeds.

Teeth of the Horse.—In order to understand the evolutionary history of the teeth it will be necessary to examine more carefully the structure of the teeth in the modern horse. If in a skull of the horse the bone is cut away from in front of the teeth, it becomes evident that they occupy most of the face in front of and below the orbits. The teeth are pushed up from the roots as fast as they wear off at the grinding surface. The incisors, or cropping teeth, form a convex row, which works with a shearing action fore and aft. The teeth have a deep valley or infolding between the inner and outer surfaces. As they gradually wear down toward the base of this valley or pit it becomes smaller and shallower and finally disappears from one after another of the teeth, until in extreme old age it has gone completely. On this account this pit, known as the "mark," can be used to tell the age of a horse, but not very accurately after eight years. Between the incisors or cropping teeth and the cheek teeth or grinders is a long gap technically known as the diastema. In the middle of this gap in the upper jaw of the male is the wolf tooth or canine, but in the female the canine teeth are entirely absent.

The cheek teeth form on each side a row of six large complex grinders above and below. The first three correspond to

the bicuspids in man, the premolar teeth of other mammals, and are preceded in the young by temporary or milk-molars. The last three are true molar teeth and have no milk predecessors. The permanent teeth, molars and premolars are all very much alike, the intermediate ones so much so that it is difficult to tell them apart. They push up from below as they wear off at the top, and in extreme old age are completely worn down to the roots. This in fact limits the age of a horse.

Pattern of the Cheek Teeth.—These grinding teeth have a very characteristic construction, which is best understood by studying the unworn tooth. In this tooth before the cement has covered it we can see that there are two crescentic ridges (the paracone and metacone), two inner crescentic ridges (paraconule and metaconule) and a flattened inner pillar (the protocone), and two smaller crests, hypostyle and hypocone, at the back of the tooth. The ends of the inner crescents are looped up to the outer pair by connecting bridges which show up as soon as the tooth becomes a little worn, and the inner pillar is similarly looped up to the paraconule. Between the inner and outer crescents are deep valleys or pits which in fact extend down to the base of the tooth. These are called the cement lakes or fossettes. A deep valley or infolding also extends in between the protocone and hypocone. On the outer face of the tooth are three prominent ridges, the parastyle, mesostyle and metastyle. These various crests or ridges are inherited in the horse from its remote ancestors, and correspond with the cusps or cones of the short-crowned teeth in most primitive mammals; but they have been enormously drawn out in the lengthening of the crown.

As the tooth crown breaks through the jaw the valleys between the crests become filled and the whole tooth covered with a heavy coat of cement. This material, deposited on the outer surface of the enamel by special secreting glands, is softer than enamel and about as hard as the dentine that forms the substance of the tooth inside its enamel coating. As the tooth wears the enamel edge always stands up as a ridge, flanked on one side by dentine, on the other side by cement. This is a very effective mechanism for grinding the food, and has been imitated in various other animals.

Structure of the Foot.—The other feature most worth especial attention in the horse is the construction of the feet.

We have already seen that the horse is a one-toed animal, the third or middle digit of fore and hind foot being enlarged, elongated and specialized to support the whole weight. In place of the five bones of the palm and instep in man the horse has a long straight cylindrical shaft, the cannon bone, with a pair of small slender tipped splint-bones lying close against its back, generally about two-thirds as long as the cannon bone. These are the remains of the second and fourth digits; of the first and fifth there is no trace left. The three phalanges or finger bones of the middle digit are short, massive, and the terminal one bears the hoof; there are no phalanges on the side toes.

The bones of the knee and hock joints, that is to say the wrist and ankle of the horse, are the same in number as in most other animals save for the absence of the trapezium which should support the first digit or thumb in the fore foot. But they are much changed in form, the facets being modified into hinge joints allowing only fore and back movement.

The Series of Tertiary Ancestors.—We have now to take up the evolution of the horse as it is presented to us in the geologic record and to observe the gradual development of these characteristic and peculiar structures, especially in the teeth and feet.

The Pleistocene species, as we have seen, are substantially like the modern ones in all except minor matters of proportion and small details of tooth pattern.

In the successive formations of the preceding Tertiary Period, we find a long series of stages through which we can trace back the ancestry of the horses to small and primitive progenitors. The genus *Equus* makes its first appearance at the end of the Tertiary in the later

Pliocene formations of the old world. With this exception all the horses of the later Tertiary are three-toed, the splints of fore and hind feet being developed as complete toes, provided with the full number of phalanges and small but perfect hoofs. These side toes are small and slender and did not reach the ground in the ordinary step of the animal. They were evidently useless rudiments or vestiges, like the dew-claws of some ruminants and of dogs. The teeth of these later Tertiary horses are shorter crowned, less completely provided with cement, the pattern different from that of *Equus*. The animals were notably smaller, the largest of them scarcely as large as a domestic ass. And all these differences from the modern species become greater as we trace them further back. In the Oligocene or Middle Tertiary we find more primitive stages. The side toes, although still slender, reach the ground and help to support the weight of the animal. The teeth are quite short-crowned and have no cement. The animals are about the size of a sheep. In the Eocene or Early Tertiary are still earlier stages, the side toes being almost as large as the middle toe, and in the fore foot there are four complete digits. In the very earliest Tertiary Paleocene we find no animals that we can regard as direct ancestors of the horses, but as all the Paleocene animals are five-toed, with a very primitive pattern of short-crowned teeth and in other respects conform to the theoretical common stock from which all the various kinds of placental mammals are derived, we may suppose that the undiscovered ancestors of the horse in the Cretaceous and earliest Tertiary were likewise five-toed, walking upon the sole of the foot, with tritubercular molars not unlike those of modern lemurs, tree-shrews and some other very primitive living mammals, and that from this primitive stock the horse and all the widely diverse types of modern animals are descended.

Looking at the evolutionary history more in detail, it is convenient to start from these primitive beginnings, and trace the development of the race upwards. As it is a record of facts we need hardly waste time on the theoretical ancestry, but begin with the earliest actual appearance of the horse phylum in the geological record.

Eohippus, the Oldest Known Ancestor.— First comes the Four-toed Horse, *Eohippus* or *Hyracotherium* of the Lower Eocene. It appears quite suddenly at a certain level in the Wasatch formation. Thousands of specimens have been secured at and above this level by expeditions of the American Museum; below it not so much as a tooth. Most of these specimens are pieces of jaws; a few are skulls and partial skeletons, and one a fairly complete skeleton, discovered in 1911. In this earliest known stage of the four-toed horses we find in the hind feet three complete toes and in addition tiny splints or vestiges which represent the first and fifth digits. They thus point back clearly to a preceding five-toed stage in the hind foot. The

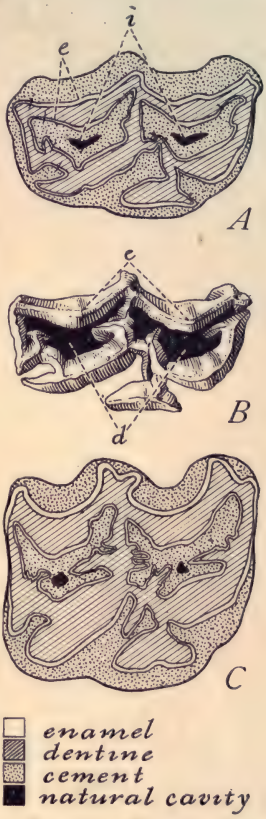

Fig. 33. Wearing surface of upper grinding teeth. Natural size.

A. Worn surface of deciduous molar (d. m. 4) of colt about 6 months old. e, exposed enamel edges; i, natural cavity in cement.

B. Unworn surface of deciduous molar (d. m. 4) of colt about three months before birth, showing only enamel. d, cul-de-sac to be filled later with cement; e, apex of folded edge of enamel.

C. Premolar (p. m. 3) of horse 8 or 9 years old.

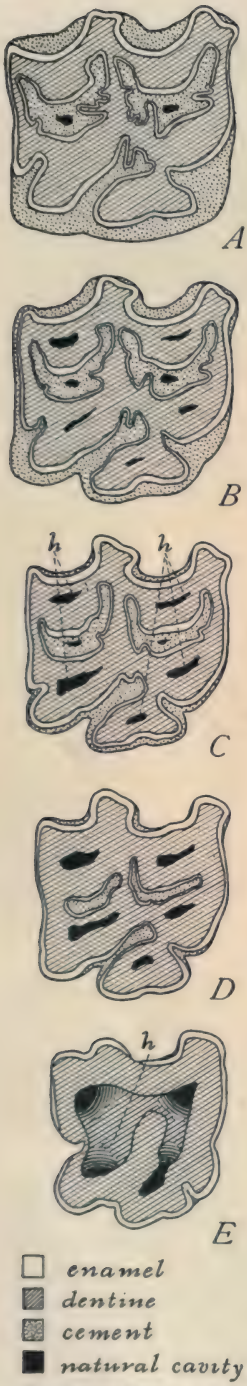

FIG. 34. Upper grinder (p. m.^{4}) of horse 10 or 11 years old cut in 5 sections; showing pattern of enamel at various ages. C, h. Branches of the pulp cavity. E, h. Pulp cavity.

fore foot shows four complete well-developed digits. But neither in this nor in any subsequent stage in ancestry of the horse, nor indeed in any member of the order Perissodactyla (horses, tapirs and rhinoceroses) recent or extinct, have we been able to discover any actual trace or indication of the inner digit or thumb of the fore foot. You will find it represented as present in *Eohippus* in most of the published descriptions and diagrams but that is an error, based on a mistaken identification of certain fragmentary foot bones studied by Professor Marsh many years ago. No Perissodactyl has any trace left of the pollex. Presumably the Perissodactyls are descended from Cretaceous ancestors which had a thumb; but such ancestors have not yet been found, so that while we have traces of five toes in the hind foot of the earliest known stage, we have only the four toes in the fore foot. The trapezium, however, is always present.

The teeth in *Eohippus* are forty-four in number, the full series being present in both upper and lower jaw. (The incisors are little simple cutting teeth, quite small. Behind them is a diastema in the middle of which are the small sharp canines or wolf teeth in both upper and lower jaw.) The premolars are smaller than the molars and quite different in form, being simple trenchant or cutting teeth, of which the last two are beginning to change shape and become more like the molars. The molars are short-crowned, with small conical cusps on the surface partly united into cross-crests with a pattern in the upper jaw somewhat like the Greek letter π, while in the lower jaw they have two cross-crests, already beginning to change into a pair of crescents. These teeth may be compared with those of the coney or dassie among modern animals, or with the modern tapir, and served to chop or break up soft food, but were not at all grinding teeth.

FIG. 35. Lower premolar (p.m.$_3$) of horse 8 or 9 years old.

The next stage of four-toed horses is from a later horizon in the Lower Eocene, and is best known from the skeleton discovered by Doctor Wortman in the Wind River valley in 1880 and described in Cope's Tertiary Vertebrata. It is the classic four-toed horse of the text-books. In this stage the tiny rudiments of the first and fifth digits in the hind foot are believed to have disappeared.

Orohippus of the Middle Eocene.—In the next stage of the Tertiary formations, the Middle Eocene, we find the genus *Orohippus*. Remains of this animal are fairly common in the Bridger formation of Wyoming. A fine skeleton was secured for the American Museum in 1905 by Mr. Granger. In *Orohippus* the fore foot has four complete digits and no trace of a pollex, the hind foot three complete

digits and no trace of first and fifth; but the middle or third digit in each foot is somewhat larger relatively to the others than the Lower Eocene four-toed horses. The teeth, while very like those of *Eohippus*, show a distinct advance in that the third and fourth premolars are larger and more like the molars in pattern, the fourth lower premolar being almost indistinguishable. The molars are somewhat more distinctly crested than in *Eohippus*.

In *Epihippus of the Upper Eocene* all these changes are a little further advanced. Skulls and partial skeletons have been found in the Uinta formation of Utah, but a complete skeleton has not yet been found. However, the various specimens agree in showing that the middle or third digit is relatively larger, and that the premolar teeth are more like the molars. The last upper and the two last lower premolars are indistinguishable from the molars, the others are partly molariform except the first, which in all the series has been growing progressively smaller and simpler. The cresting of the molars is also a little further advanced.

The Small Three-Toed Horses of the Oligocene.—These four-toed horses of the Eocene make a closely connected series. There follows a considerable gap, for the next stage, in the Lower and Middle Oligocene, is *Mesohippus*, in which the outer digit of the fore foot is reduced to quite a small splint, and the middle digit in both fore and hind foot is considerably larger than in *Epihippus* and has taken on the characteristic cylinder-shape of a cannon bone. The side toes, however, are still large enough to help support the weight of the animal. The teeth show a stage in evolution beyond that of *Epihippus* in that three premolars in upper and lower jaw are completely molariform. The crests of the molars are also slightly higher.

The next stage, *Miohippus* of the Upper Oligocene, is closely allied to *Mesohippus*, but of larger size, and slightly more advanced in teeth and feet.

The Miocene Three-Toed Horses. — During

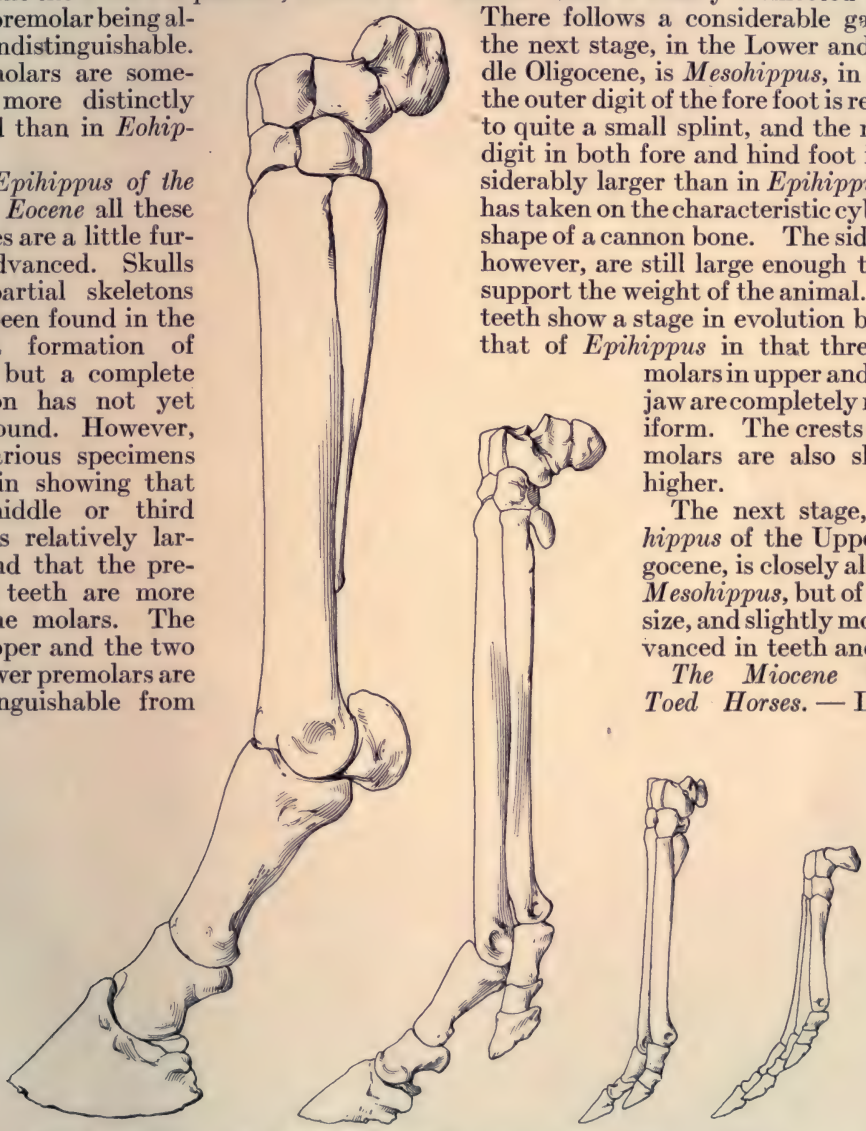

Fig. 2. Evolution of the Fore Foot. Principal stages. (Right to Left.)
1. Four-toed horse *Eohippus*. Eocene Epoch.
2. Early three-toed horse *Mesohippus*. Oligocene Epoch.
3. Later three-toed horse *Merychippus*. Miocene Epoch.
4. One-toed horse *Equus*. Pleistocene Epoch and Modern.

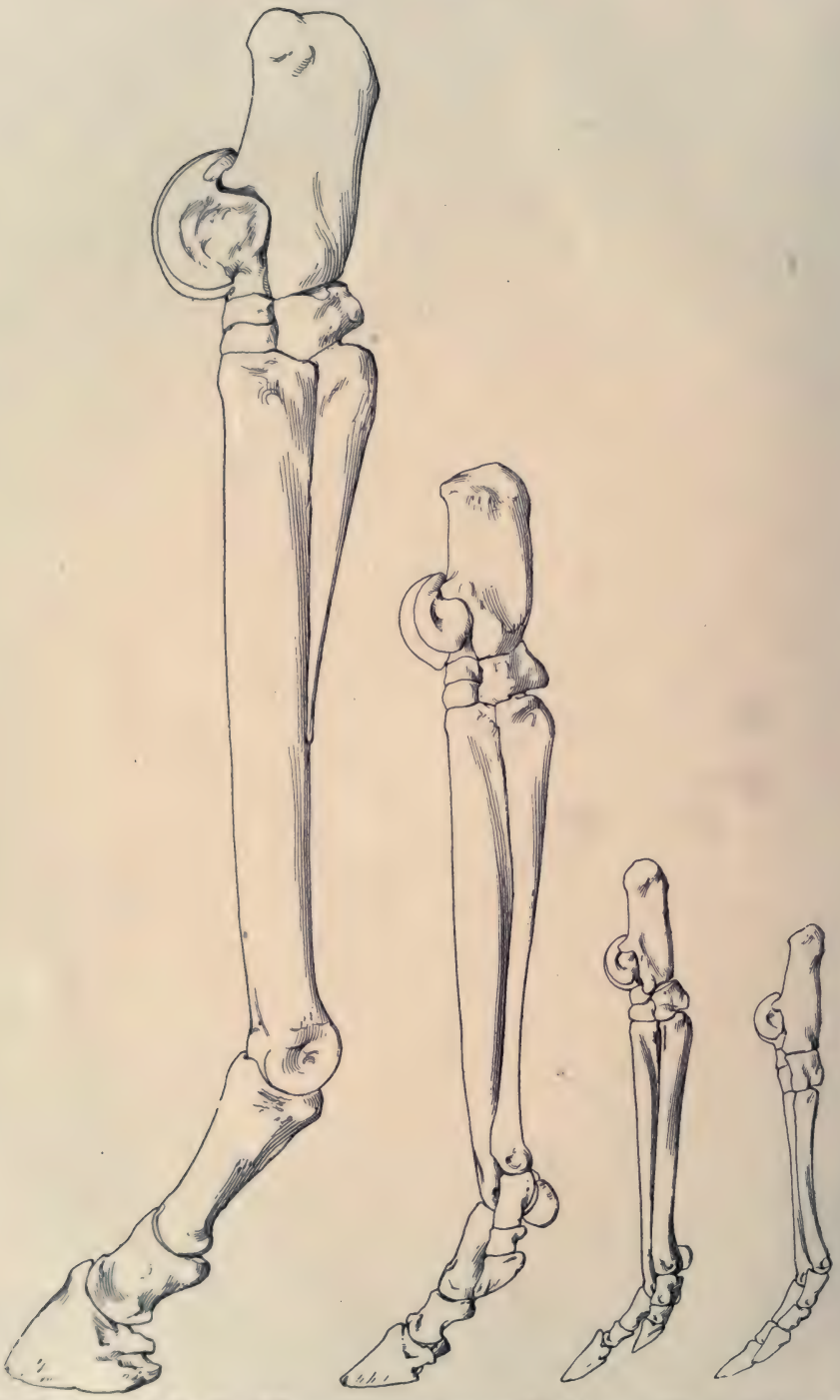

FIG. 3. Evolution of the Hind Foot. Principal stages (Right to Left). 1. *Eohippus*, Eocene Epoch; 2. *Mesohippus*, Oligocene; 3. *Merychippus*, Miocene; 4. *Equus*, Pleistocene and Modern. Outer views showing middle and outer digits. Note progressive reduction of side toe (digit IV) from a well developed digit to a splint bone.

the next epoch of the Tertiary, the Miocene, the horses enter upon a course of comparatively rapid evolution, progressing more rapidly toward the modern type, and also branching out into several races, some more advanced in one character, some in another. The beginnings of this may be seen in the ten or twelve species of *Parahippus*, the Lower Miocene genus. This genus is distinguished by the first appearance of cement on the teeth, only a thin skin on the earlier species, but considerable amount on some of the later ones. The crowns of the teeth are also progressively higher, and on some of the teeth there is always the beginnings of a bridge across the inner valley, never complete, but marking the first stage of a change from the cross-crests of the earlier species to the inner crescents of the later horses. The side toes are distinctly more reduced than in *Miohippus*, and barely reach the ground, while the middle digit is becoming more of the later type (rudiment of fifth toe smaller).

In the Middle Miocene appears the next stage in the evolutionary series, *Merychippus*. In this animal the teeth are heavily coated with cement, and the pattern of the crowns is changed to the two pairs of crescents on the upper molar, with an inner pillar which is usually separated from the crescents, although in some species it is more united. But the pillar is always round, not flattened oval as in the modern horse, and the height of the crown is not much more than the width of the tooth. In *Merychippus* the milk premolars carry very little cement, and are very like the permanent premolars of *Parahippus*. The feet are very like those of *Parahippus*, slightly more advanced.

In the Upper Miocene we find three closely related genera, apparently descended from *Merychippus*, all advanced toward the modern horse type, but some more progressive in one, some in another character. These are *Hipparion* (including *Neohipparion*), *Protohippus* and *Pliohippus*. All of them have longer crowned teeth than *Merychippus*, and in all the milk molars are longer crowned and more heavily cemented. In some species of each genus the side toes are very much reduced, the shafts of the metapodial bones being hardly more than threads, while in other species there is little progress in this respect. The upper teeth of *Hipparion* are long and but little curved with strong mesostyle, and the inner pillar in some species is flattened. The enamel is strongly crumpled in little folds on the borders of the cement lakes, as in *Merychippus* but more so. In all these characters *Hipparion* comes nearer to the modern horse than do *Protohippus* or *Pliohippus;* on the other hand the inner pillar or protocone is separate nearly to the base of the tooth, whereas in these genera, as in *Equus*, it is united to the inner crescent or protoconule.

In *Pliohippus* the teeth are equally long but the molars are strongly curved, the mesostyle is not as heavy, there is no crumpling or folding of the enamel, and the cement lakes are decidedly larger than in *Equus*. The inner pillar is united even more strongly than in *Equus* to the adjoining crescent, but it is never flattened, and the bridge is not exactly in the same place. In *Protohippus* the teeth are very like those of *Pliohippus* but with smaller lakes, and the protocone sometimes partly flattened.

Each of these three genera has been regarded as the direct ancestor of *Equus*. My own conclusion is that *Equus* is derived from *Hipparion*, but not from any of the better known species, and that the South American *Hippidium* and *Onohippidium* are derived from *Pliohippus*, again probably not from the known species.

Another interesting feature in these Miocene horses is the pits or fossæ on the side of the face. These are absent in the Eocene horses, as also in *Equus*, but are characteristic of most of the Miocene and Pliocene genera, and in the South American *Onohippidium* there is a very deep fossa. The object of these pits has been disputed; some authors consider that they lodged scent-glands; others believe that they were simply for attachment of

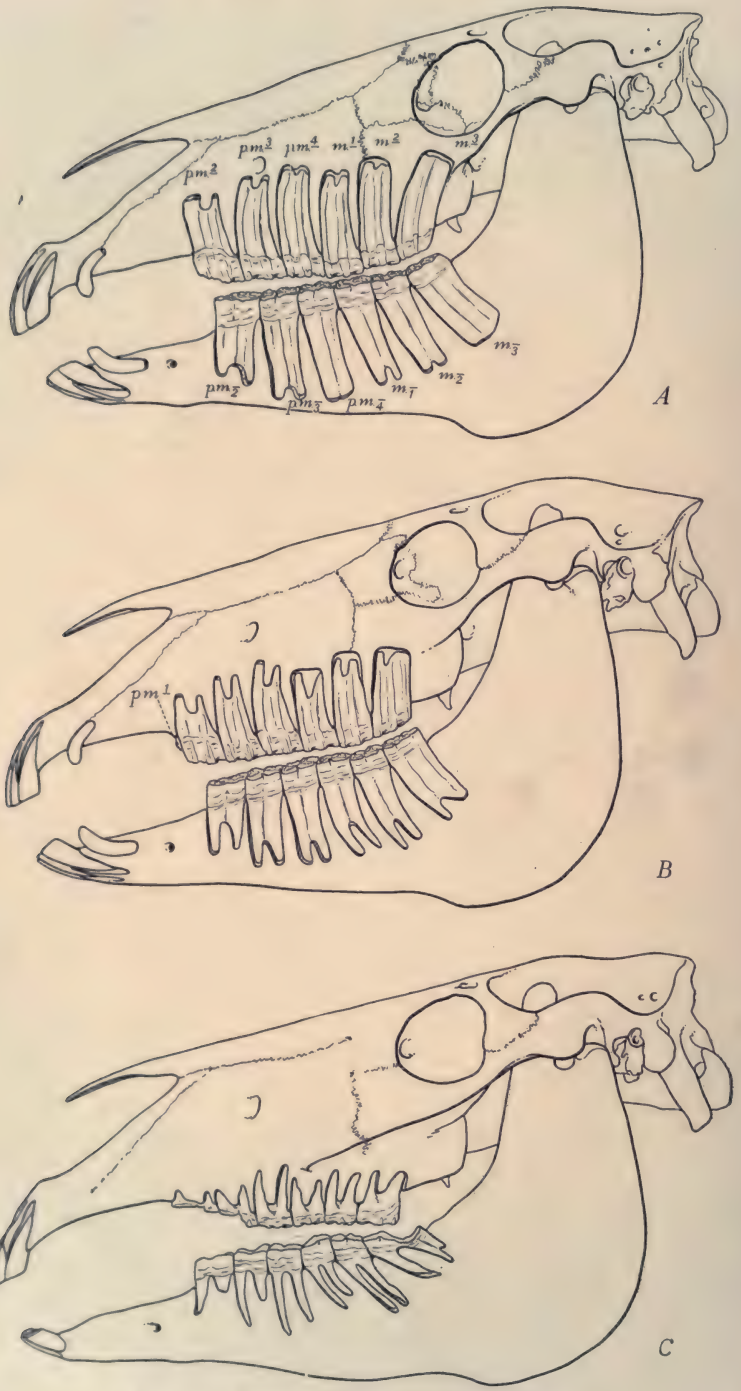

FIG. 37. DENTAL BATTERY OF ADULT HORSE

A. Skull 5 years old. Permanent teeth all in use.

B. Skull 8 years old. Crowns reduced in length by wear and roots grown longer. Vestigial p.m.^{1} present in this individual.

C. Skull 39 years old. Crowns almost worn away. Lower molars incline forward. (The canines are absent in the female.)

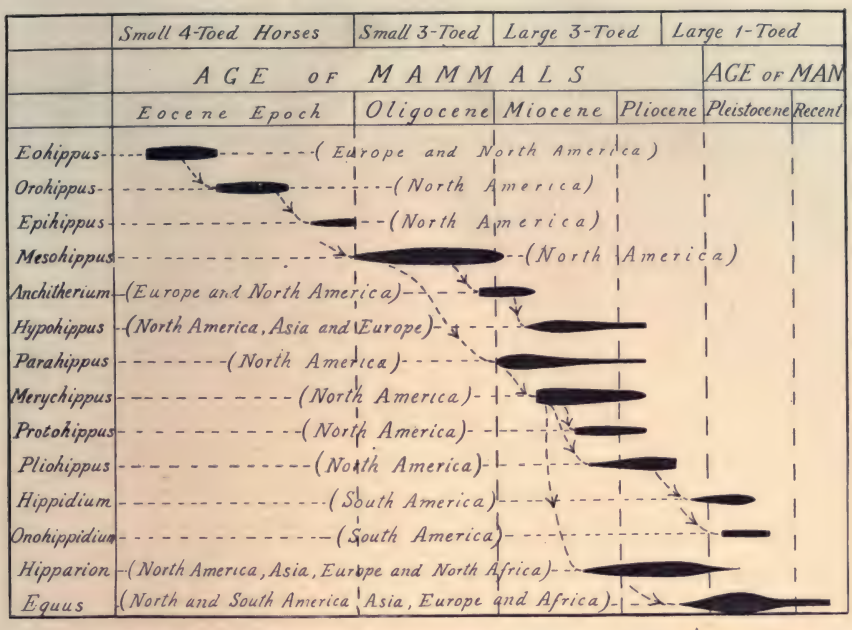

FIG. 16. Geological and geographical range of ancestors of the horse. The position and length of the heavy black lines show the occurrence and range of each genus in the successive geologic epochs, while the thickness of the lines indicates relative abundance. The dotted connecting lines with arrows indicate the genealogy.

strong muscles moving a flexible upper lip or proboscis.

Pliocene Horses.—The Pliocene record of the evolution of the horse is not as complete as we would like; and it is for this reason that we are so uncertain as to which of the Miocene horses is most nearly in the direct line of ancestry. The Lower Pliocene horses are very close to those of the Upper Miocene, but somewhat more progressive. Fragmentary material from the Middle Pliocene serves to show that the two genera *Hipparion* and *Pliohippus* continued on, increasing in size, and approaching nearer, the one to *Equus*, the other to *Hippidium* so far as I can judge from a few teeth. True *Equus* appears possibly as early as the Upper Pliocene, certainly at the beginning of the Pleistocene in North America. *Hippidium* has never been certainly identified in this continent; the species referred to it are more probably *Pliohippus*.

Is it a Direct Ancestral Series?—The ancestral series which we have now reviewed is the North American succession. How close and continuous it is may be seen by comparing the 12 stages in the upper molars. So far as the genera are concerned it is fair to say that they are in direct genetic or lineal succession. I do not think that this can be said of the species. That is to say, we cannot select a series of species occurring in geologic succession and all directly intermediate in every particular from one genus to the other throughout the series.

In most cases we must conclude that the later stage is descended from unknown species of the preceding stage. This is of course what we should expect, for the law of chance will make it very improbable that the few species of each genus which we happen to have found out of the many that must have existed in different regions at that time, should always include the direct ancestor of the following genus. In most instances each genus will be descended from undiscovered species of the preceding genus.

Centre of Dispersal.—Where these unknown species lived is a most interesting

problem. In considering it, we have to keep in mind that the regions where Tertiary fossils have been found are really quite limited. We speak of *Orohippus* inhabiting North America, but in truth all we really know is that it inhabited parts of southwestern Wyoming. Practically all our knowledge of the older Tertiary faunas of the northern world is derived from certain formations occupying limited areas in Wyoming, Utah and New Mexico, and certain others still more limited in the adjacent portions of England, France and Belgium. In the middle and later Tertiary our knowledge rests on a more extensive regional basis. But it is nowhere near enough to give us adequate data to estimate the geographic range of different species, until we come to the Pleistocene. We can judge of the regions where the new types were evolving by inferences from the geographic and taxonomic relations of the known forms. But all such conclusions are necessarily hypothetical.

Tertiary Equidae in Europe.—There is in western Europe a Tertiary series of ancestral horses, which, until the American series was discovered, was the nearest approach to an ancestral line. The oldest member is *Hyracotherium*, contemporary with *Eohippus*, and practically identical. In the Middle Eocene *Pachynolophus* and other genera are found, apparently side-branches from the direct line. In the Upper Eocene are *Lophiotherium*, *Anchilophus* and others, all of them representative of side-branches which have evolved along lines parallel to the direct series, but not ancestral. Some of these continue through the Oligocene, and then disappear. In the earliest Miocene appears *Anchitherium*, not derivable from any of these European races, but apparently from *Miohippus*. This genus is common in the Lower and Middle Miocene, but in the Upper Miocene gives place to *Hipparion*, another type apparently of American origin. *Hipparion* in turn is replaced by *Equus*, and again we find that the American species of *Hipparion* are more nearly in the ancestral line than are those of Europe. As the American series is decidedly more direct than the European series it is fair to conclude that the Western United States where it is found was decidedly nearer to the centre of dispersal of the Tertiary horses than was Western Europe. That is to say, the centre where the successive stages in the evolution of the horse evolved, and from which they spread out in different directions, was in Northeastern Asia or boreal North America. Western Europe in the early and middle Tertiary was a shifting archipelago more or less separated from the main mass of the northern continents, while North America afforded a broad and open way from the north, and was probably united with Asia during most of the Tertiary. It would seem that the immigrants from this centre of dispersal were able to spread to central North America in a pretty continuous series of waves of migration but that only three or four of these migration waves reached Western Europe. *Hyracotherium*, *Anchilophus*, *Anchitherium*, *Hipparion* and finally *Equus* in Western Europe are new invading types, each closely related to the contemporary new invading type in North America. In the intervals between these renewals of affinity, the races tend to more or less divergent evolution in the two regions.

Cause of the Evolution.—While the existence of continental connections afforded the opportunity for migration and dispersal of the successive stages from *Eohippus* up to *Equus*, I think that the fundamental impelling cause of the migration is the same as that of the evolution itself, namely climatic changes. Those who are familiar with Professor Ellsworth Huntington's work, will recall how closely he has connected human migration movements with cycles of climatic change. I believe that the migrations of Tertiary animals were also caused by climatic changes driving them out in all directions from the central Holarctic regions where, on account of their nearness to the poles, the oncoming changes of climate were first and most severely felt.

And to this same cause, the secular

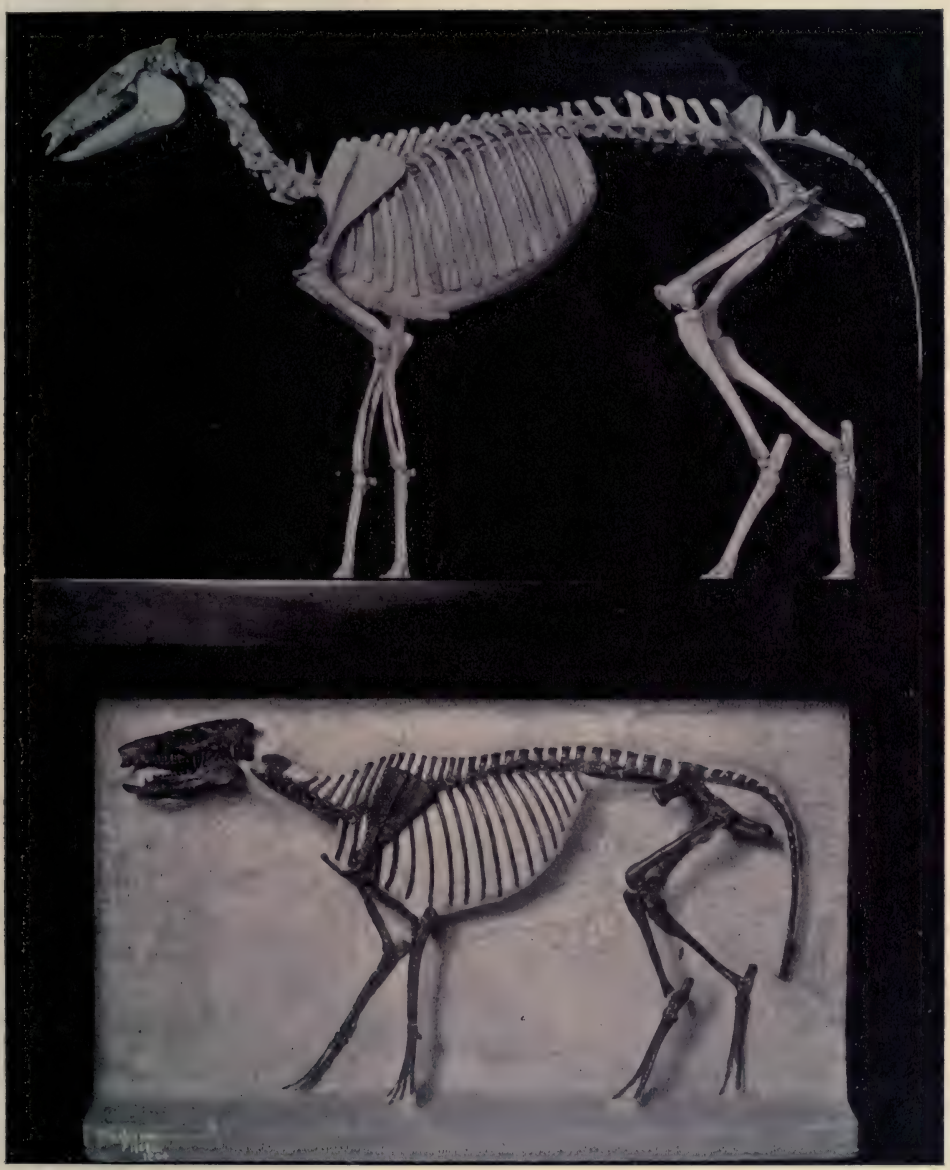

Fig. 8. Little three-toed horse (*Mesohippus bairdi*) from the Middle Oligocene of South Dakota. American Museum, No. 1492.

Four-toed Horse (*Eohippus renticolus*) from the Lower Eocene of Wyoming. American Museum, No. 4832.

EOHIPPUS, THE FOUR-TOED HORSE
Reconstruction of the earliest known Ancestor of the Modern Horse, discovered in the bad lands of Wyoming.

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change in climate during the Tertiary from uniformly warm moist semi-tropical conditions to the contrasted climates of the present day, with highly varying seasons, cold at the poles and arid in the interior of the great continents—to this change I conceive that the evolution of the horse was fundamentally an adaptation. For such a change in climate involved the replacing of dense forests by open plains and arid deserts. It resulted in the replacement of trees and shrubs by grasses, of animals adapted to the irregular obstructed travel of the dense forest by animals adapted to the open level surfaces of the grassy plains, of browsing by grazing animals. It brought about the adaptation of the animals of the great open interior plains to swift movement over level ground to traveling long distances for water and endurance of extremes of cold, to feeding upon the hard wiry grasses of the arid plains. And the evolution of the horse from its little four-toed browsing brush-haunting ancestors of the Eocene went hand in hand with the change in climate, the spread of the grasses and open plains, and the progressively harsh environment of the far north.

THE TILEFISH

THE attention which has recently been given to the tilefish, which is now being taken in large quantities from New England waters, makes its recent local history interesting. This fish was discovered in 1879 off Nantucket, and a specimen was sent to the United States Fish Commission, which pronounced it a new species. The fish was found in large quantities and had excellent food qualities, but just as tile fishing promised to become a profitable industry the fish were apparently exterminated in some mysterious manner. In the spring of 1882 an area of 170 miles long and 25 miles wide off New England was covered by dead tilefish. The displacement of the Gulf Stream is given as an explanation.

The tilefish lives at the bottom and requires a rather high temperature. The warm water of the Gulf Stream no longer extended to the bottom and the fish perished in the cold water.

SPREAD OF FUNGUS BLIGHT

THE Pennsylvania Department of Forestry has been making exhaustive investigations with a view of finding out the means of the dissemination of spores of blight fungus which are the causes of numerous tree diseases. There is most convincing evidence that insects are principally responsible for the spread of spores, although a large number of them are, of course, carried by the wind. The result of these investigations suggest also that the spread of other plant diseases is directly traceable to the action of insects.

THE "NOBLE" GASES

HOW THE "NITROGEN" OF A GENERATION AGO HAS BEEN MADE TO YIELD SIX, AND POSSIBLY SEVEN ELEMENTS AND THE VALUE OF THIS DISCOVERY TO CHEMISTRY

BY HENRY P. TALBOT

FROM the earliest days of quantitative chemical experimentation the atmosphere has been the subject of frequent investigation. The discovery of oxygen as a separate entity resulted from the independent researches of Priestley in England and Scheele in Sweden about 1774, and nitrogen had been recognized as a new gaseous substance by Rutherford in 1772. The part which these two gases play in the atmosphere was demonstrated a little later, and for more than a century the literature contains innumerable records of physical and chemical measurements based upon the assumption that these two elements constitute the sole essential constituents of the gaseous envelope of the earth. Other substances, such as moisture, ammonia, and carbon dioxide, are, to be sure, universally present, but are accidental components, varying in amount according to local conditions, while oxygen and nitrogen are to be found in approximately constant proportions, no matter where the specimens of air may be collected.

Such was the universal belief when, in 1893, Lord Rayleigh, an English physicist, undertook to review the measurements of some of the natural constants of the more common permanent gases, among them the density of nitrogen gas. He was profoundly astonished to discover that "nitrogen" obtained from the atmosphere after removal of the other constituents, according to the then accepted methods, was distinctly heavier, volume for volume, than nitrogen obtained from the decomposition of chemical compounds of which it is a component. The differences were much too large to be accounted for by errors in manipulation or observation, since these were accurate to about one part in ten thousand, while the discrepancies in weight were of the order of one part in two thousand.

When this announcement was made public, speculation as to the cause of the observed difference in density was rife, but it soon became highly probable that a search must be made for a new element in "atmospheric nitrogen," as the residual gas which remains after the removal of the other constituents from the atmosphere is now called. To this search Lord Rayleigh and Professor (now Sir William) Ramsay addressed themselves.

They first employed a method which was a repetition of work done nearly a century before by Cavendish. An electric discharge was passed through air in the presence of an alkali. This causes the oxygen to combine with a part of the nitrogen and the products of the combustion are absorbed by the alkali. In this way the oxygen can be removed, and the residue is "atmospheric nitrogen." Nitrogen is a comparatively inactive element in a chemical sense, but it can be made to combine directly with certain of the metals, such as magnesium, and by repeatedly passing the residual gas over the metal until no more diminution in volume occurred, they obtained a small quantity of a gas which was twenty times as heavy as hydrogen (taken as a standard) whereas nitrogen is only fourteen times as heavy. This final residual gas was found to amount to a little less than 1 per cent. by volume of the original air. These results were confirmed by other and different procedures, and in 1895 the

two co-workers felt justified in announcing the discovery of a new element, to which they gave the name argon, the inert; a name which later investigation has justified since argon has resisted all attempts of the most varied character to induce it to enter into chemical combination with any of the other elements.

It is interesting to note that Cavendish just missed the discovery of this element, for in the record of his experiments we find that, when sparking a mixture of nitrogen with an excess of oxygen, he obtained a residue of which he says: "If there is any part of the phlogisticated air (now called nitrogen) of our atmosphere which differs from the rest and cannot be reduced to nitrous acid, we may safely conclude that it is not more than one-one hundred and twentieth of the whole." The residue was undoubtedly argon, and it is remarkable that this record should have passed unnoticed for more than a century.

The chemist conceives that any given element is not indefinitely subdivisible by chemical agencies. He terms the ultimate particles atoms and further conceives that compounds are formed by the union of atoms of different elements. It is not possible to determine with accuracy the absolute weights of these atoms in terms of any units of weight in common use, but it is possible to determine the relative weights of the atoms of different elements, in terms of the weight of the atom of hydrogen taken as a standard. When a new element is discovered, almost the first concern of the chemist is to fix a value for its atomic weight on this hydrogen scale. Although argon, as already stated, forms no chemical compounds, it was found possible from its physical constants to fix upon a value for its atomic weight with much probability of truth. But a fresh difficulty then presented itself, namely, that this new element did not fit into the so-called periodic system of the elements. Mendelejeff has found that, if the known elements are arranged in the order of their atomic weights, those elements which have generally similar properties recur periodically in the resulting system. But argon, with an atomic weight 40, which was the value found for it, would be out of place; that is, it would be associated in the system with very dissimilar elements. Since repeated determinations of the atomic weight made upon different specimens of the gas confirmed the figures first obtained, and since, according to the periodic system, the value seemed to be too large, a search was begun for possible small admixtures with the argon of a second new element with larger atomic weight.

At this time it was recalled that nitrogen had been found in the gases occluded in certain minerals, and it was suggested that argon might also be found in these gases. Professor Ramsay collected a considerable quantity of the gases from a mineral called cleveite, and these did contain argon, but they also yielded another new element, although not the one for which they were searching. In this discovery the spectroscope played the principal part. It is known that highly heated gases give out light which when examined with the aid of a prism is found to be different from sunlight, in that it does not produce a continuous spectrum. The heated gases emit light of certain definite wave-lengths, which appear as bright lines in different parts of the spectrum. These lines can be charted with great exactness and have a constant position for a given element. Sir William Crookes, who made the spectroscopic examination of the gases from cleveite, reported the presence of an element yielding lines identical with those shown in the spectrum of the sun's chromosphere during an eclipse, and ascribed as far back as 1868, by Lockyer, to an element which he called helium. Later measurements confirmed the identity of the lines in the spectrum of the new gas with those of helium and density determinations showed that this element has an atomic weight of 4 on the scale indicated above. It could not, therefore, account for the discrepancy in the atomic weight of argon, but its discovery clearly pointed to the existence of other elements of the general character of argon. It

should be noted in passing that the similarity of the spectra of argon and nitrogen, as well as its inert character, largely account for the failure to detect its presence in the atmosphere for so long a time.

Thus stimulated, the search for other inactive elements was continued. A considerable quantity of argon from the atmosphere had been laboriously collected, and preparations were made to liquefy it and subject the liquid to fractional distillation, that is, to allow it to evaporate slowly, collecting the gases evolved in separate portions or "fractions," the first of which would contain a larger proportion of that element which boiled away most readily, just as alcohol tends to boil away first from a mixture of alcohol and water in the radiator of an automobile. These "fractions" were then separately liquefied, and each, in turn, refractionated, in this way gradually separating the more volatile from the less volatile constituents. The same procedure was applied to the residues obtained upon the evaporation of liquid air. Indeed, without the use of liquid air, and liquid hydrogen, as refrigerating agents, or the skill in manipulation of liquefied gases obtained through the handling of liquid air, together with the perfection of the evacuated double-walled Dewar flasks, the isolation of the different inert gases would not have been possible.

The separation by means of fractional distillation had to be supplemented by other physical methods, namely atmolysis, or diffusion through minute openings; and later, the adsorption of gases in the pores of willow-charcoal at low temperatures. The less the density of a gas the more readily it diffuses, hence by passing a mixture of gases of different densities through something like the stem of a clay pipe, the lighter gas is made to pass through the pores at a more rapid rate than the others and may be collected from the outside.

By combinations of these three procedures, fractional distillation, diffusion, and selective adsorption in charcoal, it has been possible to isolate and identify five members of this wholly unique group of gases, often called the "noble gases" because of their apparent disinclination to associate themselves with other elements. The elements are helium, neon, argon, krypton, and xenon. The first two are lighter, the last two heavier, than argon. Notwithstanding the discovery of the two latter elements, the anomalous position of argon in the periodic system is still unexplained, since they are not present in sufficient amounts to alter appreciably the atomic weight determination. The other members fit into the periodic system without difficulty.

A sixth member has recently been added to the group in the discovery of niton, the emanation given off by radium compounds in the first step of their disintegration. This has been obtained in amounts weighable only by specially constructed balances of remarkable accuracy, but, notwithstanding the great difficulties to be overcome, its atomic weight has been determined with probable accuracy, and its chemical inertness established. There is some reason for suspecting the existence of a seventh "noble gas," lighter than helium, which because of its small mass would not probably remain in the earth's atmosphere but would be attracted by the larger heavenly bodies, and would even then probably be found only in the outer portions of their atmosphere. Spectral lines have been detected from the sun's corona, emitted by some substance outside the zone of hydrogen or helium, and these lines are not identical with those of any terrestrially known element. The name coronium has been tentatively assigned to this element,—just as helium was named by Lockyer in 1868,—and it may be another "noble" gas.

Five members of this group, helium, neon, argon, krypton and xenon are found in the atmosphere, and niton is probably present in most minute amounts. The proportions of the other gases seem to be about as follows:

Helium, 1: 185,000; neon, 1: 55,000; argon, 1: 106.3; krypton, 1: 20,000,000; xenon, 1: 170,000,000.

Liquid air is the source of all of these gases today, except helium, which although present in liquid air is more read-

ily obtained from the gases occluded in certain minerals, as noted already. Neon has offered the greatest difficulties in purification.

The discovery of a series of elements without any chemistry, such as had been unknown and possibly unimagined, was, of course, sufficient to excite great scientific interest, after a certain period of incredulity as to the validity of the discovery had passed. Their scientific importance is further enormously enhanced by the discovery that helium is a product of the disintegration of radioactive materials, and that all terrestrial helium probably owes its origin to this source. There is no direct evidence at present that any of the other inert gases, except niton, have a similar origin, but the final conclusion on this point has yet to be reached.

Helium remained unique for some time after its discovery as the only gas which it was impossible to liquefy. Even Dewar, so skilled in such methods, was unsuccessful, but Onnes, building upon the foundation laid by Dewar, has succeeded, and has produced liquid helium in considerable quantities. Its boiling-point is about 4° above absolute zero, that is, about −269° C., and Professor Onnes has conducted a series of most valuable investigations upon the effect of this temperature (the lowest at our command) upon physical phenomena, notably electrical phenomena. One of the most striking results of his investigations is his demonstration that an electrical current induced in a lead ring placed in liquid helium continues to flow for a long time after the exciting cause is removed; that is, electrical resistance nearly disappears at that temperature. It is evident that this opens an immense field for experimentation and speculation.

Argon is now comparatively easily obtainable from liquid air, provided it is not necessary to purify it from the small amounts of the other inert gases, which do no harm in argon for technical purposes. It has already found commercial use in the "argon lamp," the successor of the nitrogen lamp. Formerly the bulbs of the tungsten lamps were evacuated as completely as possible, but it was subsequently found that if these lamps were filled with nitrogen at atmospheric pressure they could be run at a higher temperature and greater efficiency without too great evaporation of tungsten from the filaments. This is supposed to be due, in part, to the collision of the molecules of tungsten as they leave the surface of the filament with those of nitrogen gas, which drives many of them back to the filament. Since argon has a heavier molecule than nitrogen, and is completely inert, it has been substituted in these lamps, with a resulting further increase in efficiency.

Krypton, notwithstanding the minute proportions in the atmosphere, is possibly intimately connected with the phenomena of "northern lights," since the spectrum of these lights shows the lines of krypton with considerable prominence.

From a scientific viewpoint niton is the most unusual of these elements, since it possesses two characteristics which were absolutely unknown in 1895, namely, complete chemical inactivity, and a temporary existence due to atomic disintegration, the discovery of which has given rise to a new primary science, radioactivity. Niton has already been used, in aqueous solution, as a curative agent in radiotherapy. The nature of the changes involved could not be made clear without a somewhat extensive presentation of radioactive phenomena in general.

Although of comparatively little practical value in themselves, the discovery of these noble gases, closely associated as two of them are known to be with the story of radium and its congeners, has had an enormous influence upon our present concepts in physics and chemistry which is daily bearing fruit. What the future may bring is beyond the compass of our imaginations, but new ground has been broken, which has permitted us to delve a little deeper into the foundations of scientific knowledge. Old concepts have been confirmed and broadened (very few destroyed) while vast unsuspected stores of energy in common matter have been revealed, which only our ignorance of today prevents us from using for the purposes of life.

WORLD METEOROLOGY

WEATHER VARIATIONS OVER THE EARTH'S SURFACE GENERALLY CONNECTED AND THEIR RELATION TO FOOD SUPPLY AND TO BUSINESS CONDITIONS VERY MARKED

BY H. HELM CLAYTON

THE knowledge of the ways of the weather necessarily began at single isolated spots—a knowledge of what is going on in the sky above our back yards, so to say. We are now struggling to enlarge our knowledge of the weather to embrace the whole world.

The earliest observations were of clouds sky-colors, signs in the sky and of the behavior of animals and of plants. This knowledge was embodied in sayings and rhymes, such, for example, as

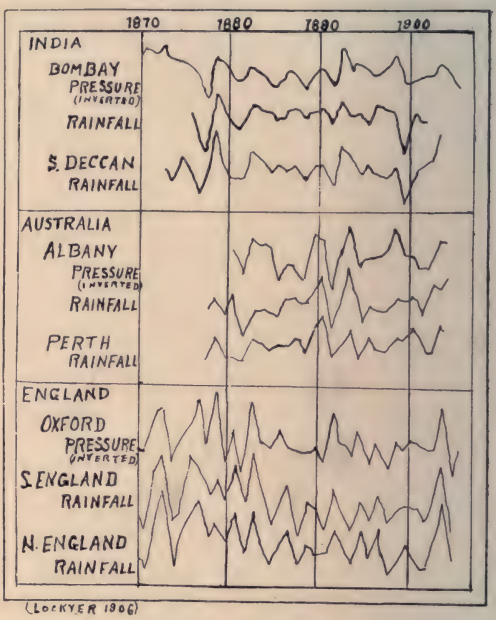
"A rainbow at night, shepherds' delight."

or

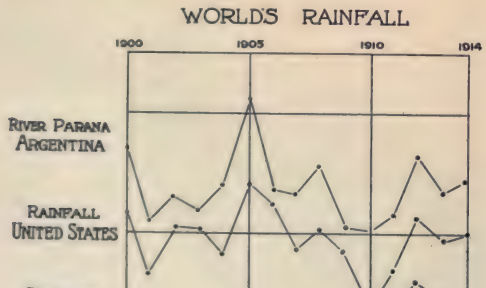
"Evening gray and morning red,
Will pour down rain on traveler's head.
But evening red and morning gray
Will set a traveler on his way."

Each cloud received its special name, the highest clouds being called "cirrus." This species of clouds is formed of fine films of frozen vapor at heights of five or six miles in the air; then there is a class of clouds formed of filmy cloud sheets which received the name "cirro-stratus." Another type formed of small, rounded flakes, resembling the back of a mackerel, received the name of "cirro cumulus." The large heavy masses of clouds, which float in a summer sky and frequently form into thunder showers, received the name of "cumulus"; while the rain clouds received the name of "nimbus." To these names in recent years have been added other names and combinations such as alto-cumulus and alto-stratus, but a logical, scientific nomenclature is yet for the future.

The early stage of weather study con-



Comparison of the relation between rainfall and pressure in different parts of India, Australia and England.



Taking weather observations in winter on top of Mt. Washington.

sisted in observing clouds, their changes and developments, and even today the study of clouds is one of the most fascinating branches of meteorology. Next came the invention of instruments for measuring changes taking place in the air, such as thermometers, barometers and hygrometers. These instruments were observed by careful and interested students in various parts of the world, and slowly a body of scientific knowledge about the weather at isolated spots began to grow up.

It is uncertain who was the first to

Observatory on top of Mt. Blanc, Switzerland.

discover the relations between weather changes at one spot and those at distant points, but Benjamin Franklin, in our country, is credited with being the first to observe that storms move from place to place. He was attempting to observe a lunar eclipse in Philadelphia in coöperation with astronomers in Boston but was prevented by clouds and rain from observing in Philadelphia. He later learned that observations had been obtained in Boston, and with his natural inquiring mind he also ascertained that the rain which prevented his observation occurred a few hours later in Boston. Subsequent inquiry developed the fact that this was the usual occurrence. Following Franklin in our country came Espy, Redfield, Loomis and Henry, who worked out a knowledge of the law of storms, showing that these were phenomena which extended over hundreds of miles of territory and, in the United States, generally progressed from West to East.

After this knowledge became general there began the organization of national weather services. The first of these was made in France, but the ones in America followed only a few years later, with the organization of a national weather service in the United States in 1871, and in Argentina in 1872. These weather services began the scientific gathering

Weather map of February 12, 1893, 8 p.m. Rainfall area shaded dark and cloud area shaded with lines.

Weather map of February 13, 1893, 8 a.m. Rain area shaded dark and cloud area shaded with lines.

of observations from points scattered all over the areas of the various countries, for the use of commerce and agriculture, and later undertook the making of weather forecasts for one day in advance. For the making of these forecasts telegrams are received at a central point from all the important stations in the country; charts are drawn up which become pictures of the various weather conditions over large areas and permit the central office to follow these changes from place to place and to anticipate their occurrence.

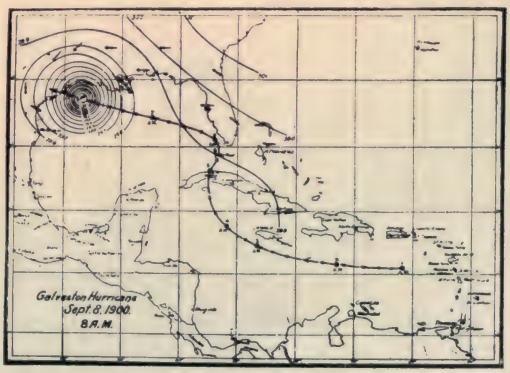
The most important of these changes in weather are the cold waves which sweep down from the polar regions preceded by storms of rain or snow, hurricanes, which sweep up from the tropics carrying destruction in their train, and the tornadoes, which devastate small areas particularly in the central part of the United States.

The West Indies hurricanes are storms of heavy rain and violent wind three or four hundred miles in diameter, which have their birth in the West Indies, move northwest and strike the American coast near the latitude of Florida or Texas, and then, changing to a northeasterly direction, pass off the coast of the United States into the Atlantic Ocean. The city of Galveston has twice been wrecked by hurricanes of this description, and in the past these hurricanes have been the terror of the ship captain. The worst of them leave in their train hundreds of wrecked vessels, and vivid tales of danger and hardships have been told by those who escaped the fury of some of these storms.

To better anticipate the coming of these storms a well organized observing service is now being instituted by the United States in the West Indies.

The tornado is equally violent, but over a much smaller area. Its path is usually only two or three hundred yards in diameter, but within that area there is usually complete destruction. Owing to their limited area and destructiveness, observations of these storms are almost impossible. There are only one or two instances on record where records from instruments have been obtained within their path.

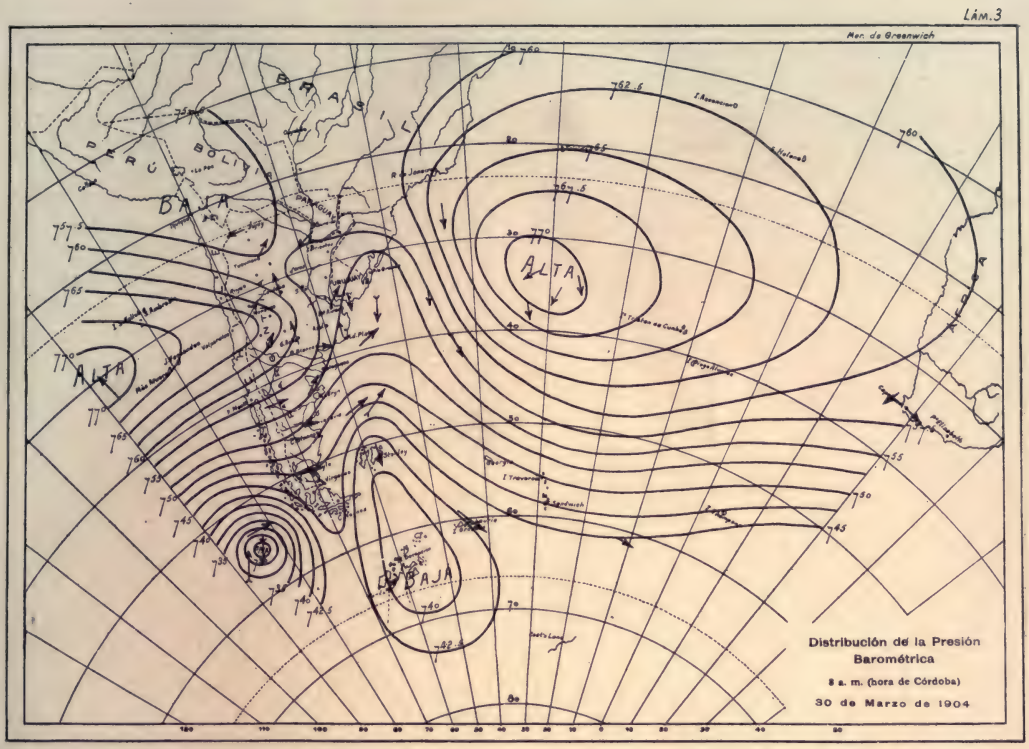
The observations made for the various weather services of the world are confined



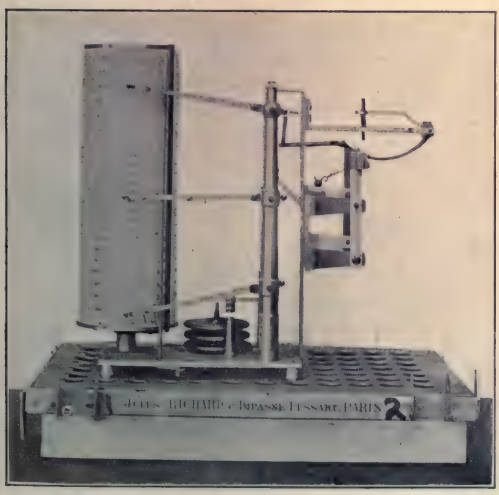
Kite, kite reel, recording instrument and other apparatus used in making observations in the upper air at Blue Hill.

Instrument elevated by kites at Blue Hill.

to the land areas of the best organized governments, and there remain vast tracks of ocean and of land in which there are at present no organized sets of weather observations. To obtain additional data observations are taken over the ocean tracks by the regular steamers, and occasional observations have been taken outside of the regular ways of ocean travel by steamers fitted out to make scientific observations. I spent four months on one of these steamers fitted out by Teisserenc de Bort and Lawrence Rotch, exploring the air currents above the ocean. Observations as a rule, made by weather services, are confined to the air near the ground, but to make progress in the knowledge of the world's weather it is necessary to know something of what is going on in the air at great heights. As a beginning in obtaining knowledge of these conditions, observations were



Daily map of the pressure and winds in the southern hemisphere March 30, 1904. Published by the Oficina Meteorologica Argentina.

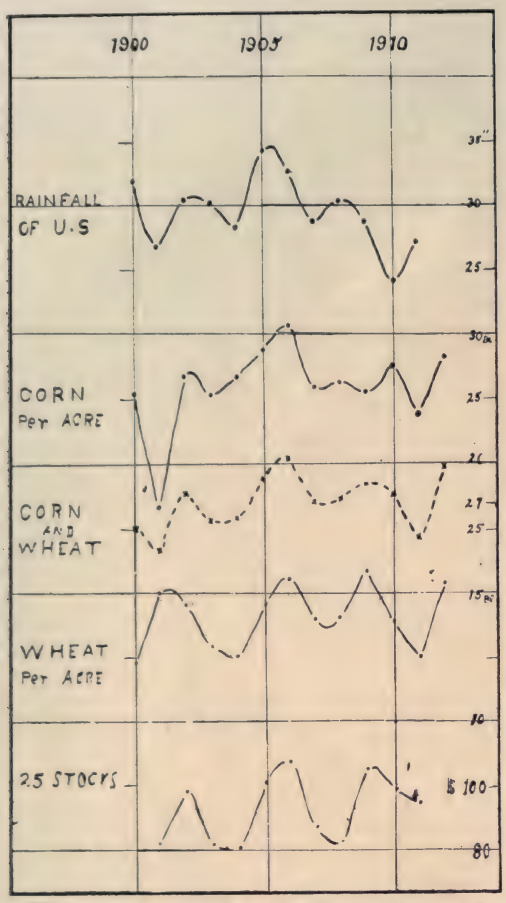


Recording parts of instrument lifted by kites.

undertaken on mountain summits, and stations have been established on the tops of many of the highest mountains in the world; but their results have been so complicated by the effects of the mountains themselves on the air, that the knowledge of the general law of the air has not been advanced greatly by the observations taken on these summits.

Another method of observing is in balloons, by which the observer is carried through the clouds to heights of four or five miles, but is prevented from going to greater heights owing to the decreasing density of the air. In the early attempts to observe the air in balloons several observers lost their lives by trying to rise to heights where life is impossible.

In recent years a safer method of observing and comparing weather conditions aloft has been made with instruments carried on kites. This method developed at Blue Hill was later adopted by the leading weather services. These in-



The annual rainfall in the United States, the total production of corn and wheat and the average price of securities showing the intimate relation between rainfall, crop production and business conditions.

struments have always been carried to heights of four or five miles in the air by kites, but the latest and best method of studying the conditions of the upper air was originated by Hermite in France and is by means of small balloons carrying recording instruments. These are left pilotless and free to follow their own course. They contain cards attached to the balloons giving the name and address of the person who launched them and offering a reward for their safe return. In this way a large part of the balloons and their records are recovered. These balloons have now reached a height of twenty miles in the air and have given the first real knowledge of what takes place at great heights in the earth's atmosphere.

The national weather services of the United States, France, Germany, England, Belgium and Argentina have taken an active interest in these researches.

The combined observation on mountains and with kites and balloons have shown that the air grows steadily colder as one rises above the earth's surface until the height of five to seven miles above the earth's surface is reached where the temperature, even in midsummer, is always far below zero. But above the height of seven miles the temperature rises again and continues to rise up to about twenty miles; the highest point yet reached by observing balloons. The place of lowest temperature in the air has been found highest near the equator and lowest in the polar regions, and it is for this reason that the lowest temperature of the air is found over the equator, because at a similar level in the colder region the temperature has begun to rise with increasing height above the ground.

These observations with balloons have also shown how rapidly the air moves from one region of the world to another.

At one time I made a voyage from St. Louis to New York in a balloon in about forty hours, using for this purpose the currents about a mile above the earth's surface. Other balloonists have gone even greater distances in a less time.

But perhaps the most interesting knowledge of the movements of the atmosphere as a whole have come from the outbursts of volcanoes, when great volumes of dust and smoke are thrown into the air and can be followed as they drift from point to point. One of the most remarkable of these volcanic outbursts was that of Krakatoa in 1883 when the dust was thrown to heights exceeding fifty miles. Krakatoa is near Java in the East Indies, and the dust from this volcano drifted within two weeks completely around the earth in the equatorial zone, moving at the rate of about seventy-

five miles an hour from east toward west. Within a few weeks the dust had spread northward and swept rapidly around the earth in the opposite direction, from west to east.

Air currents have also been followed from place to place over the earth's surface by means of dust elevated in dry regions by local whirlwinds. A body of dust raised in this manner was followed in 1901 from the Sahara Desert northward to north Germany and France in three days, and in 1903 a dust cloud was followed from eastern Africa out to the central Atlantic and thence northeastward to England, where it fell with the rain and gave an appearance of raining blood, a phenomena observed several times in English history, and interpreted as indicating dire disasters to follow. The dust storm of 1903 moved from the eastern coast of Africa to England within two days. Such observations as these show how great a rover is our atmosphere. The air which fans the tropics today may become a part of the air which we breathe in New York or Boston two days later, and the air which is driving in fierce storms across the Arctic ice today, two or three days later may be carrying a cold wave far southward toward the tropics.

Observations in various parts of the world have indicated that the winds of the world are arranged in belts, generally from some easterly direction near the earth's surface in the tropics and from some westerly direction near the surface in the temperate zones. The prevailing directions at great elevations remain yet more or less of an uncertainty, although we know that in the equatorial regions the general tendency is from the east at all heights up to about six or seven miles, while in the temperate regions the prevailing winds are from the west at all heights up to five or six miles. Above these heights the prevailing directions are as yet more or less uncertain.

Besides the waves of weather, which make up our day to day changes, there are now known to be larger, slower changes which form our periods of weather, as for example, periods of warmer or colder weather, or periods of wet and dry weather, which also drift from place to place in our atmosphere but more slowly than the changes which make the rapid day to day changes.

Again, it is also becoming known, by comparing the weather in widely separated parts of the earth, that there are large seasonal changes of weather, such as wet and dry seasons, or cold and hot seasons, in which the same kinds of variations take place in widely separated countries, while opposing variations take place in intermediate areas of the world. For example it is known that the weather conditions of India and Australia vary in an opposite sense to similar variations in Siberia and Argentina. It is also known that the rainfall of central South America and the rainfall of the United States follow very much the same general trend; while the rainfall of the tropical regions, as at Trinidad and North Africa, follow an opposite course, so that at times of excessive rain in central South America and in central North America are times of deficient rain or droughts in the West Indies and vice versa. It is thus becoming evident that the weather conditions over the entire earth's surface are more or less connected, and are probably dependent upon some factor outside of the earth itself. Just what that factor is remains yet to be determined with certainty, but the general belief is that it will be found associated with changes in the sun.

A considerable body of workers have been engaged in such researches, the most active of whom are Hildebrandsson, the Lockyers, Arctowski, Mossman, Exner and Craig.

These large weather changes, which make up seasonal variations play an exceedingly important part in human affairs. Rainfall in temperate regions determines the amount of crop production, and the subsequent food supply of the world. These variations in the food supply of the world are reflected in widespread variations in business conditions. The welfare of the railroad, of the ship-

ping industries and of commerce generally depends upon an abundant supply of food material, and when this is deficient, wide-spread business depression follows; so that variations in our business conditions follow a parallel variation in the rainfall of the world. Periods of excessive rainfall are invariably followed by periods of improved business conditions, and periods of deficient rainfall are followed by depressions in business, and in this way the variations in the rainfall influence the whole of human life.

HOW TO MAKE A FIREPLACE

Few fireplaces furnish a perfectly even combustion at all times; nearly all draw noticeably better on very cold days than on warm, murky days, and better in certain winds than in others. But it frequently happens, says the *Youth's Companion*, that the fireplace persists in sending smoke into the room. It then becomes a household torment that spoils tempers with its irritating smoke, and treacherously ruins the festive occasion it is supposed to serve. The visitor at old farmhouses is often surprised at the number of fireplaces that he finds sealed up.

The commonest defect in a fireplace is a lack of proper proportion between the area of the fireplace opening and the area or cross section of the inside of the flue or chimney. It should be as ten to one. When it is larger than that, more air is mixed with the heat, smoke, and gases, and the flue is unable to carry off the whole without artificial aid. If you discover that the mouth of your fireplace is more than ten times the area of the flue opening, you can reduce the former by placing a hood across the top of the mouth of the fireplace; but take care that the design of the hood is not out of harmony with the style and the lines of the fireplace.

The second common defect in fireplaces is the slanting throat. The mason who builds the throat of the fireplace with a slant (see AB in Fig. 1) is obviously thinking only of the column of hot air that comes from the fire, curves past the nose, B, and goes easily on and up. Thinking of the problem in this way, he sees no particular harm in making AB on a slant.

But in reality every household chimney must accommodate not merely one column of air, but two. Unless the fire has been hot for a long period and the draft is exceptionally strong, there will be a column of cold air coming down the chimney and striking at A. When AB is on a slant, this thin column of cold air slides down and meets the smoke and gases coming up from the fire. The result is to drive the smoke and gases—usually in little puffs—into the room.

The correct way to build the throat is to have AB flat, as shown in Fig. 2. Then the column of cold air rests on AB, and, curling up at the base, goes up in almost frictionless flight with the stream of hot air. The chimney then has a draft.

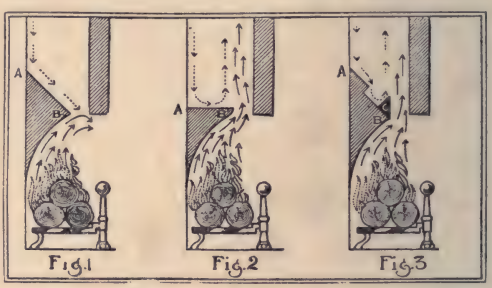


Fig. 1 Fig. 2 Fig. 3

An intelligent mason who discovers that his predecessor has built AB on a slant will knock out the row of brick at B, and then build a slight "retaining wall" of cement along the edge of the nose, three or four inches high (C in Fig. 3.). This "retaining wall" will keep the thin stream of cold air from sliding down into the fireplace and forcing smoke and gas into the room.

The two defects here described usually result in smoke, but there are fireplaces that, although they do not smoke, are "listless" and have poor drafts. They have to be fed with very dry wood, and tended with absurd care. Generally they can be much improved by extending the chimney ten or twelve feet in height. Sometimes—although not always—the additional draft can be obtained by placing on the chimney a revolving top.

SCIENCE CONSPECTUS

VOL. VI 1916 No. 2

A COMPARATIVE COLOR PHOTOMETER

ANNOUNCEMENT OF A NEW SYSTEM FOR THE STANDARDIZATION AND CHARTING OF COLORS AND ALSO FOR SCIENTIFIC COLOR SYNTHESIS

BY ARTHUR HOWLAND

THE Photometer is essentially a light tight box with a slide in the front having a small opening through the aperture of which the operator sees the absolute black of the interior. It contains a small high speed motor with a shaft arranged for clamping discs of paper or thin cardboard, which may be spun close behind the opening. The motor is screened from view by a second partition covered with black velvet, while a third screen back of the motor aids in absorbing any light rays which might otherwise find their way to the black velvet which covers the back of the box on the inside. By this method the background is so completely screened that the effect on looking into the opening is one of absolute black. In operation, the machine should be so set up, that light will enter only in the direction indicated by the arrow in Fig. 1, while the operator should stand directly in front of the box with his eye at the level of the opening and about fifteen feet away.

Sectors of all sizes from 0 to 100 per cent. similar to those shown in Fig. 2, are provided, with ends carefully coated with magnesium carbonate. Colored sectors of the same pattern are furnished in a few of the strongest colors obtainable.

With this outfit it is then possible to produce practically all known colors in every conceivable strength or luminosity. Mixing a white sector with the black of space gives an absolutely pure neutral gray of any desired luminosity as set by the size of the sector chosen, from a blacker black than any known pigment, to a purer white than has ever been produced in papers or pigments.

Mixing a colored sector with the black of space, gives the deeper shades of the same color or by using the white sectors in conjunction with the colored ones it is possible to make grayer or lighter tones of the same color. Again, by combining any two of the colors provided, in this same way it is a simple matter to produce any color desired within the limits set by the strength of the working colors used. To make the machine of practical value, it is necessary to discover very strong and pure colors.

Also it is quite essential that the colors be laid upon the sectors with an absolutely colorless medium as any oil or varnish vehicle would tend to discolor them to a marked degree.

After fully two years of research work such colors have been obtained and a method of applying them to fine white card stock has also been found. If at any time stronger colors are discovered

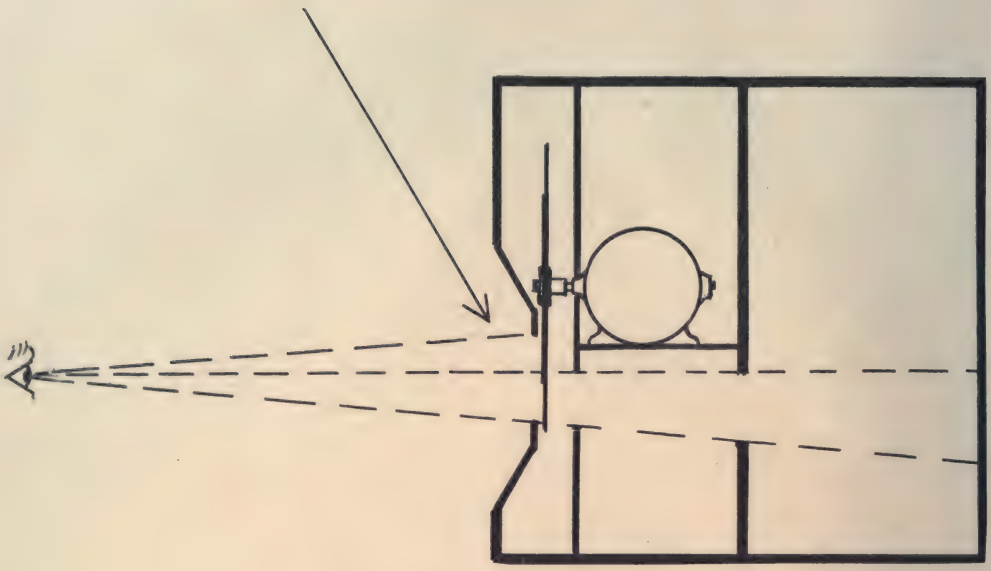


FIG. 1

they will simply increase the range of usefulness of the apparatus to within their own limits of strength.

Since all possible combinations of color may be made with this photometer, it is practically an easy matter to study the geometrical relationship of pigment colors with a view to charting them for commercial as well as educational purposes. Incidentally it has been found practical to place them with such accuracy that all combinations may be figured mathematically by using the three properties of color, hue, strength, luminosity.

THE CHART

The photometer is best used in conjunction with a chart which might well be called a "colorless" color chart (see Fig. 5) since there are absolutely no colors upon it, although every point of its entire surface may represent a different color or varying luminosities of the same color for any one spot.

It has long been known that every color has its opposite or "complementary" color, the combination of which will always give gray if spun in the proper proportions for exact neutralization.

By imagining each color as projected down upon a horizontal plane, we are enabled to use ratios of distances between them just as easily as if it were possible to take the measure of the actual distances in space. To illustrate,—if R (Fig. 3) is a certain red situated above a given plane and R′ is its projection upon that plane, and if G and G′ are respectively the position and the projection of a certain green, then if we wish to make a color Y intermediate between R and G, it is only necessary to spin the red and green discs together in the ratio of a′ parts of red to b′ parts of green to get the resultant color Y, which in this case is a dull yellow, since a′ is to b′ as a is to b. (In this case 3 to 5.) Suppose that our red has a luminosity of 27 per cent. of that of our standard white and that the green has a luminosity of 25 per cent., then to figure the resultant color, we use the following form,—

Area	*Luminosity*
R 37.5 per cent.....	.10125
G 62.5 per cent.....	.15625
	.25750

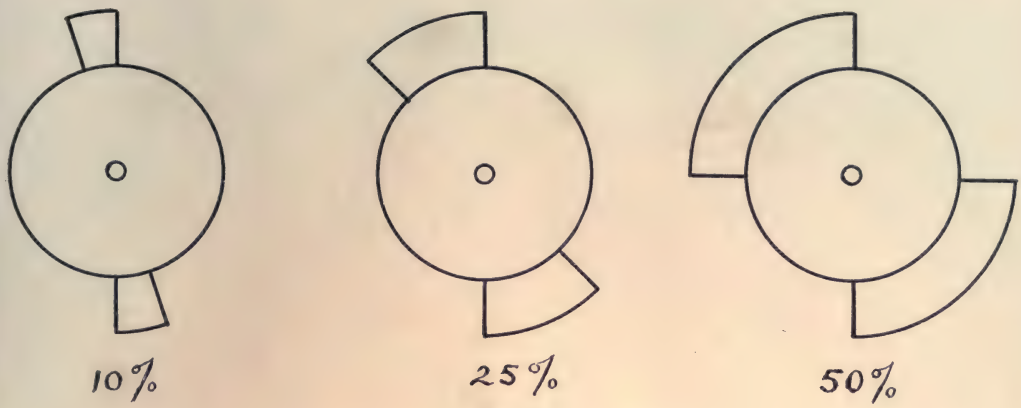


Fig. 2

This means that the resultant color, yellow, has a luminosity of 25.75 per cent. if made from the red and green above mentioned.

To produce this result the discs should be set as shown in Fig. 4.

All known colors may be placed about a neutral axis in space and will actually

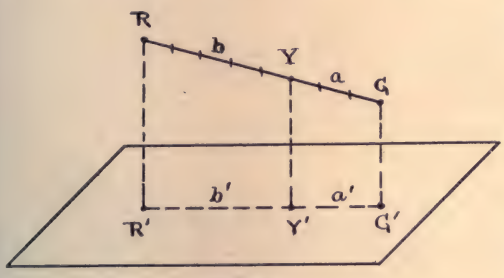


Fig. 3

respond with mathematically exact spinning ratios to the above method of procedure, provided they be properly located in their true positions according to their three properties of hue, strength and luminosity. By knowing the luminosity of the comparatively few working colors on the prepared discs and sectors, it is a very easy matter to figure out beforehand what color will result from any possible combination.

As there are endless combinations that can be made, it is also possible to figure combinations of other colors that will produce identically the same resultant and the color photometer will actually permit of making both at the same time. For an example,—take the above red and green in the proportions given to make a dull yellow. At the same time spin sectors of a strong yellow and white (with the black of space) on the same shaft with the red and green. (Fig. 6)

If the proportions of all of these colors used are taken from the horizontal chart as figured from the point where the lines between the components cross, it is an easy matter to figure both sets with such accuracy that the two combinations will match absolutely even though it may never have been done before.

If a strong yellow Y (Fig. 5) has a luminosity of 80 per cent. and the chart shows a ratio to the meeting point Y′ of say 18 per cent. of the yellow to 82

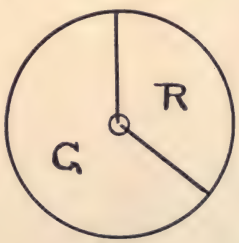


Fig. 4

per cent. of neutral gray N (black and white) the equation would stand as follows,—

R 37.5 %...	.10125	equals	Y 18 %...	.1440
G 62.5 %...	.15625		N 82 %...	.1135
	.25750			.2575

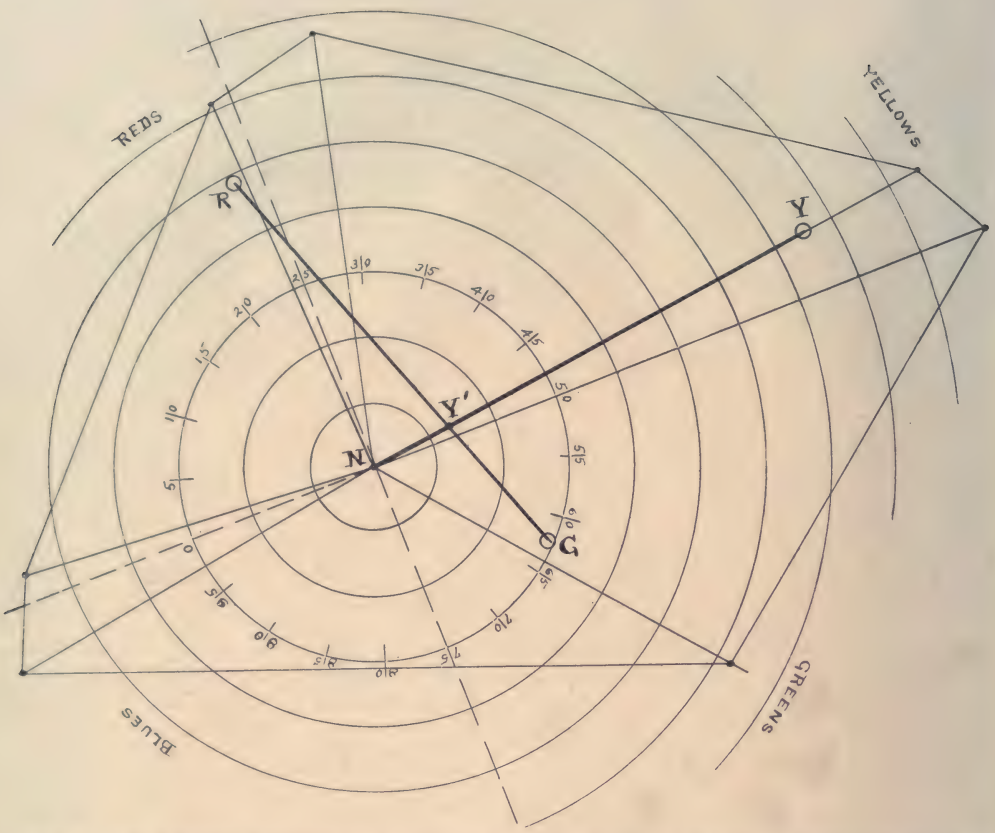


FIG. 5. The diagram represents the "plan view" of an imaginary color solid containing within its limits practically every known pigment color. The reader may be considered as above the drawing looking down upon the highest point of the solid at N, which point represents the upper or white end of the neutral axis containing all possible grays from absolute black to white. The lower or black end rests upon the plane of the paper.

Each of the limiting points of the diagram may be considered as the projection upon the plane, of various colors of great strength whose hues vary with their angular positions about N in exact accordance with the order of the spectrum through red, orange, yellow, green, blue, violet, and whose positions above the paper are fixed by their respective luminosities. Their relative strength is indicated by their distances from point N radially outward as 10, 20, 30, etc., and is determined by the concentric circles. Note that between the blues and the reds will be found all purples which are seen only in spectral colors when spectra overlap, the violet end of one with the red end of another.

While the placing of colors upon a chart in this manner is purely an imaginary one, it is nevertheless a fact that when properly placed they will respond with marvellous accuracy to exact laws of combination which this figure portrays. As soon as three color points have been determined, all other colors must then occupy fixed positions with respect to them.

Such colors will then obey the law of moments of forces with mathematical accuracy where the spinning area times the strength of one will always equal the spinning area times the strength of the other when opposed to each other as complements.

Moreover, when once a few strong colors have been properly located upon this chart, it is then possible to figure in color and solve problems mathematically, predicting the exact resultant color in all three of its properties of hue, strength and luminosity.

It will be noticed that the diagram is very nearly a true parallelogram, with the four colors red, yellow, green and purple-blue at the four corners. It should, then, be possible to produce all colors lying within these bounding points from a combination of these four with black and white. That such is actually the case, may be most beautifully demonstrated by the use of four such powerful working colors in the photometer described above.

Therefore the colors Y′ would be identical, since their position on the chart indicates their similarity of both hue and strength, and their luminosities are both .2575 as compared with the same standard.

These, of course, are very simple examples of what may be done with the machine in an educational way, but they lead to very remarkable possibilities with the refinements that are bound to come in the future.

It is always possible to retain a sample of the working colors in the dry powder form, which if kept in the dark in glass containers will not fade or change in

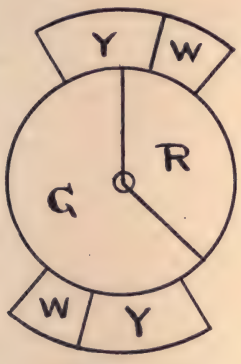


Fig. 6

any manner, so that they will always give a standard with which to work. If, then, a color is once matched to the standard *made from these working colors*, it is always possible to produce again the same standard from these working colors by taking some of the dry color which has been kept under proper conditions and placing it upon fresh discs and sectors. Manufacturers abroad could have working colors from the same pigments as standards and could reproduce any point upon the chart that might be indicated by American distributers. Such points could be indicated in several ways with great accuracy. While the actual percentage of each working color used in any given case might be easily cabled, a better way would be to designate each color wanted by three numbers indicating in order, the hue, the strength and the luminosity.

The three numbers, 23–49–31, for instance, stand for one color only, namely a red R (Fig. 5) whose hue is 23 per cent. of the angular distance from a point of lowest luminosity in the circle of spectral hues taken as 0, whose strength is represented by 49 units of distance out from the neutral point N, and whose luminosity is taken from comparison with the standard white used and is found to be 31 per cent.

An American manufacturer can match a piece of goods to his combination of sectors, locate it upon his own chart and cable the result to Paris or London, to any house that has a similar outfit with the certainty that under the same lighting conditions an absolute match will be obtained. Under ordinary conditions daylight from a north skylight will give satisfactory results but for very accurate matching it will be found that it is better to do the work by the aid of an incandescent lamp outfit with a screen and voltage regulator similar to some of those now upon the market for this very purpose.

Educationally, the photometer should be a wonderful aid to teachers and supervisors, who would be able to illustrate to their classes the exact composition of any given color, the relation of one color to any other, the harmony of different hues of the spectral circle, the complete separation of luminosity from hue or strength, and last, but not least, the fascinating process of producing new colors that have never been equalled in pigments. The machine is so sensitive that it will analyze even a black pigment, showing with great accuracy the percentage of red, or blue or green that is in it and making it possible to correct it to a completely neutral black.

There is probably no manufacturing process today, that does not use color in some form and it will undoubtedly be used even more generally in the future when some such standard will come into general use throughout the civilized world.

THE PROTOATOM OF A WORLD

A SUGGESTED COSMOGONY TO ACCOUNT FOR THE EVOLUTION OF A STELLAR SYSTEM WITHOUT THE NECESSITY OF MATTER BEING ORIGINALLY PRESENT

BY L. B. BUCHANAN

SEVERAL theories of celestial evolution have been elaborated by able minds and have received the appreciative consideration of the thinking public. The nebula hypothesis of La Place, with modifications introduced by later astronomers and the alternatives presented by Professor See and by Professor Lowell, are so well known as to need no description here.

All of these theories deal with the agglomeration of matter as such, by various probable methods, into stellar systems such as our own solar system and those which our galaxy reveals. Whether the origin be considered as gaseous, as meteoric dust, or as the result of near approach or collision of dark or visible stars, in all cases matter identical, or analogous to what we know as such, is presupposed to exist and be involved. Whatever action supposed to take place is accounted for on the theory of universal gravitation continuously acting.

Quite recently the writer, who is not an astronomer—in fact is only what might be called a commercial scientist—had the privilege of talking with one of the foremost astronomers of the world. The general subject of these remarks being touched upon, that eminent authority expressed himself to the effect that the astronomer does not ordinarily go into the constitution of matter in his investigation of such subjects.

The writer's courage in perambulating the infra-red precincts of cosmic evolution may therefore partake of the fearlessness of fools. Fully conscious of this, he is nevertheless about to embark on this adventurous course, with the hope that what he here sets forth, if patently unsound to the informed, may awaken a new line of thought in some readers.

Not necessarily as a substitute for the great theories mentioned in the first paragraph, but merely to be considered simultaneously therewith, is presented the following quasi-theory of cosmic evolution, which proposes the building of a stellar system, or of a galaxy, without of necessity any matter as such, originally present in the region of construction.

The theory presupposes the existence of the ether, the existence of one or more galaxies, the formation of atoms from electrons, the emanation and movement of electrons with velocities from zero to almost the velocity of light, the transmission of light by electromagnetic waves in the ether, the transmutation of so-called elements by radio disintegration, as evidenced terrestrially by uranium, radium, etc., the conservation of energy and continuity. Universal gravitation continuously acting is not presupposed; but gravitation is assumed as a universal property of all organized matter of the kinds with which we are familiar.

No new property of the so-called ether is prescribed. We can conceive of no limit to universal space, no beginning nor end to time and no beginning nor end to the universe, it presumably always was and always shall be.

Always there have been celestial bodies radiating electromagnetic waves and electrons in all directions, the waves always so far as we know with constant velocity, the electrons with all magnitudes of velocity up to that approaching the velocity of the waves themselves. Detached electrons are undoubtedly affected by electromagnetic waves, as for instance the repulsion of small particles by light waves, by electrical action upon each other, possibly by a resistance to motion

in the ether itself, possibly also by gravitation but scientists believe that any gravitational action of electrons is small compared with the electrical actions.

With the preceding in mind, consider in a large region remote from organized celestial systems a collection of electrons which have come from various radiating bodies and by virtue of various reactions and interactions have, relatively to each other and possibly absolutely, almost no motion, the probability is that the space density of these electrons will not be uniform, that by virtue of interference-wave residual effects, their distribution may be analogous to that of the sand on a vibrating plate after it has come to rest. Electrons of higher velocity may be continuously passing between them, changing their relative positions and likewise similar effect may result from electromagnetic waves from the remote stellar organisms, whence they themselves came. Let us consider that none of these electrons are in close enough proximity, or proper orbital relation, to constitute an atom of any matter which we know, but rather that the whole group, which let us imagine occupies several cubic light years of space, is at a particular instant one great protoatom, with little kinetic energy but with enormous potential energy, let us classify it as an ultra-mega-uranium, possessing enormous atomic weight, but owing to its loose organization and susceptibility to disturbance, having almost an infinite rate of decay. Imagine the decay to go on with the formation of smaller but still enormous protoatoms, each such successive decay occurring with increase of kinetic energy, radiations, loss of electrons, splitting off of groups, capable of becoming hydrogen, helium, etc., just as we observe in the case of terrestrial radium, recalling also the sustained temperature of radium above surroundings. Consider as a possibility the occasional happening of a configuration corresponding to that existing in known elements, that is, a resonator capable of responding to proper excitation, let the excitation be the repeated impetus received from some electromagnetic wave or combination of them coming from remote stars, we then by reason of the existence of an eternal element determine its persistence; like begetting like. Possibly some of the chance stable configurations resonate to electromagnetic overtones, in which case we have perhaps prescribed a condition of procreation of analogous rather than identical matter. So soon as we admit the formation of known matter, even if not before, we will gain the assistance of gravitation in the condensation of our proto-nebula. With increased kinetic energy and closer grouping of the electrons, we would expect the protoatom to disappear, always with relatively large amounts of hydrogen and helium as products, the occasional production of other known elements and possibly many mega-uraniums, matter far down the scale from the protoatom first considered, yet much more active as to rate of decay than any radio-active element we know.

Now what as to the temperature of this proto-nebula? We have seen that the evolution considered, means the giving out of energy in enormous quantity as radiation and expelled electrons; such action may well be capable of being seen from a remote distance, therefore the above question. First we must be sure we know what we mean by temperature; if we conceive of ether as incapable of possessing temperature, and for example, that in a given region of interstellar space there is one molecule of gas per cubic centimeter, no thermometer that we know would tell us anything about the temperature of that space, if we mean by temperature the kinetic energy of the gas in it. If on the other hand we mean the temperature of some discrete mass, as a thermometer or a meteoric stone which happens to be there, we must know the relative absorption and radiation rate of the mass, which will vary for every different shape, size and kind of mass. For present purposes we will take temperature to mean the heat intensity measured by the kinetic energy of the gas molecules and with our relatively widely scattered molecules in our sup-

posed proto-nebula we may have a high temperature but a small quantity of heat. Our nebula is hot, in that its mean molecular vibration velocity is high, but a ponderable body therein may be cold because there are not enough molecules or radiations striking it to make it take up heat faster than it radiates it, after a very slight rise. Any condensed nodule in the nebula might therefore act as a condenser for matter it came in contact with. Cold nodules might thereafter coalesce with such evolution of energy as to raise their temperature; indeed having generated our matter for the construction of a stellar organism from the electrons that came from those organisms which were before, we may choose any of the theories of condensation of the nebula which pleases us.

It should be remembered that the question of temperature may be of maximum importance in considering hot celestial organisms, or for that matter terrestrial matter heated to temperatures higher than those subject to past research, on account of the possibility of endothermic combinations at those temperatures and pressures, which would be impossible at temperatures with which we are workingly familiar.

In order to get a rough idea of what we have herein considered, the following approximate calculation has been made.

The nearest star is of the order of 4 light years away, consider the sun controls to ½ that distance, viz., 2 l. y., for simplicity's sake a cube of space whose side is 4 l. y. The volume of this space is 64 cu. l. y. or approximately 13 x 10^{39} cu. miles.

Consider the entire solar system to be equivalent to a sphere 1,000,000 miles in diameter, of density 1, a volume of approximately 5 x 10^{17} cu. miles weighing 2 x 10^{33} grams. Let this be imagined distributed in primeval state substantially uniformly throughout the 64 cu. l. y.; the amount of matter per cu. mile would then be 1.5 x 10^{-7} grams. A cubic mile is roughly 4 x 10^{15} c.c., therefore the matter per c.c. = 4 x 10^{-23} grams. Imagine for example that the matter is water vapor, of which at standard temperature and pressure 1 c.c. weighs 8 x 10^{-4} grams; we then have $\frac{4\times10^{-23}}{8\times10^{-4}} = .5\times10^{-19}$ of the amount present in a standard c.c. Assuming a standard c.c. of gas to have 10^{19} molecules, there would be ½ molecule per c.c. average density. At 20,000 electrons per molecule there are 10,000 electrons per c.c. Assuming them placed equidistant they would average about ½ m.m. apart. The relation of this distance to their distance apart in ordinary matter is of the order of the relation of the distance between members of the solar system, to the distance of the farthest stars from the sun.

A comparatively short interstellar distance has been chosen for this example; we can conceive of the region occupied by the protoatom as being so remote from any star system as to include many hundred cubic light years instead of the paltry sixty four above considered, in which case the electron density could be very much less than what has been shown and yet the aggregate would be more than the entire solar system.

Consider our galaxy 40,000 l. y. in diameter and the space which it occupies included by a cube of that dimension, viz., 64 x 10^{12} cu. l. y.; on the basis of the same electron density assumed in the previous calculation, there would be matter enough to construct 10^{12} solar systems.

If we assume that our sun is an average star, we have provided for more by 5,000 fold than Roberts calculated on the basis of 4,000 stars per square degree, which he found in a rich portion of the Milky Way in Cassiopea, assuming that density to hold throughout the sphere, and more by far even than the same sort of calculation derives based on the Omega Centauri Cluster. This would certainly allow for enough dark stars to satisfy those who believe they greatly outnumber the visible ones and perhaps for enough to explain the velocities of 1830 Groombridge, Arcturus and Mu Cassiopea, which Professor Newcomb found anomalous, considering only visible stars.

Recent computations have arrived at

10^8 as the number of stars visible in our largest telescopes and from the fact that successively larger telescopes have not disclosed proportionally more stars, it is believed to be a reasonable approximation to the total number of visible stars. If we allow tenfold that number, viz., 10^9; the original electron density of our calculation is 1,000 times too great, so under the previous assumption that our sun is an average star, we could account for the entire galaxy with an original density of 4×10^{-26} grams per c.c. Strangely enough this would be just about the density of matter which Professor Schiaparelli calculated would completely intercept all light within the distance of the visible limits of our galaxy.

While this discussion has been confined to the generation of a stellar organism, there is nothing to preclude consideration of a similar action taking place in a smaller way within our sun's domain, in which case we must look to the comets as the little descendants of protoatoms formed from stalled electrons, within gravitational reach of the solar system.

A highly speculative attempt to build a world from mere electrons has here been made; if, as some of our leading scientists have thought, electrons are merely vortices in the ether, our world has been built from ether, not spontaneously but in a measure like ourselves, offshoots of those which were before. Thus the ovum of stellar life is the electron, a carrier of energy which changes from kinetic to potential and *vice versa*, is bartered and borrowed, but is never lost so long as continuity is assumed; the milt that starts the life may be the electromagnetic waves from the remote parent bodies.

Far beyond the infra red of the spectrum may be the line autographs of protoatoms whose vibrations are so slow and feeble that though their wave length is enormous compared with the longest Hertzian waves we know, the amplitude is so small that detection by any resonator of the high periods we are constrained to use is impossible. The protoatom thus may be beyond our senses, but some of the intermediary line of descent toward atoms of our acquaintance may be disclosed to future searchers for the truth Possibly the summational waves resulting from combinations and recombinations of the long waves above conceived may come into our sense scale, provided we can find the means to sufficiently keen our senses to the necessary observation; the Rosetta stone which shall make sensible that which is beyond direct impression.

Referring back to the subject of gravitation. Let it be said that biased by our experience which is consistent and identical, we always think of inertial mass and gravitational mass as one and the same, a little consideration will show that this is not necessarily true. If there was a coherent substance which was repelled by the earth and by all substances we now know, or if it were neither attracted nor repelled, we have no difficulty in imagining it to possess inertial mass, although in one case there would be negative, and in the other, no gravitational mass. If there were any such permanent substance ever on the earth it has long since been repelled to a remote distance, so that our inability to find such is no proof of the impossibility of its existence.

Such a substance may be possible by proper arrangement of electrons under the right conditions, high temperature may be essential, perhaps such substances exist temporarily in the sun and stars but decay to matter of ordinary properties before they get away, owing to drop in temperature. Such substances may be present among our protoatoms, if so the effect of gravitation may not always be present at all points in the proto-nebula. Inertial mass has been found to increase with velocity, but no direct observation of corresponding increase of gravitational mass has been reported nor has the question of whether gravitation has a finite velocity of transmission been determined.

In considering cosmogony, it is essential to take as broad a view of possibilities as may be permitted to tellurimental intelligence; with a plea for, if not a practice of, this attitude the above crude effort is submitted.

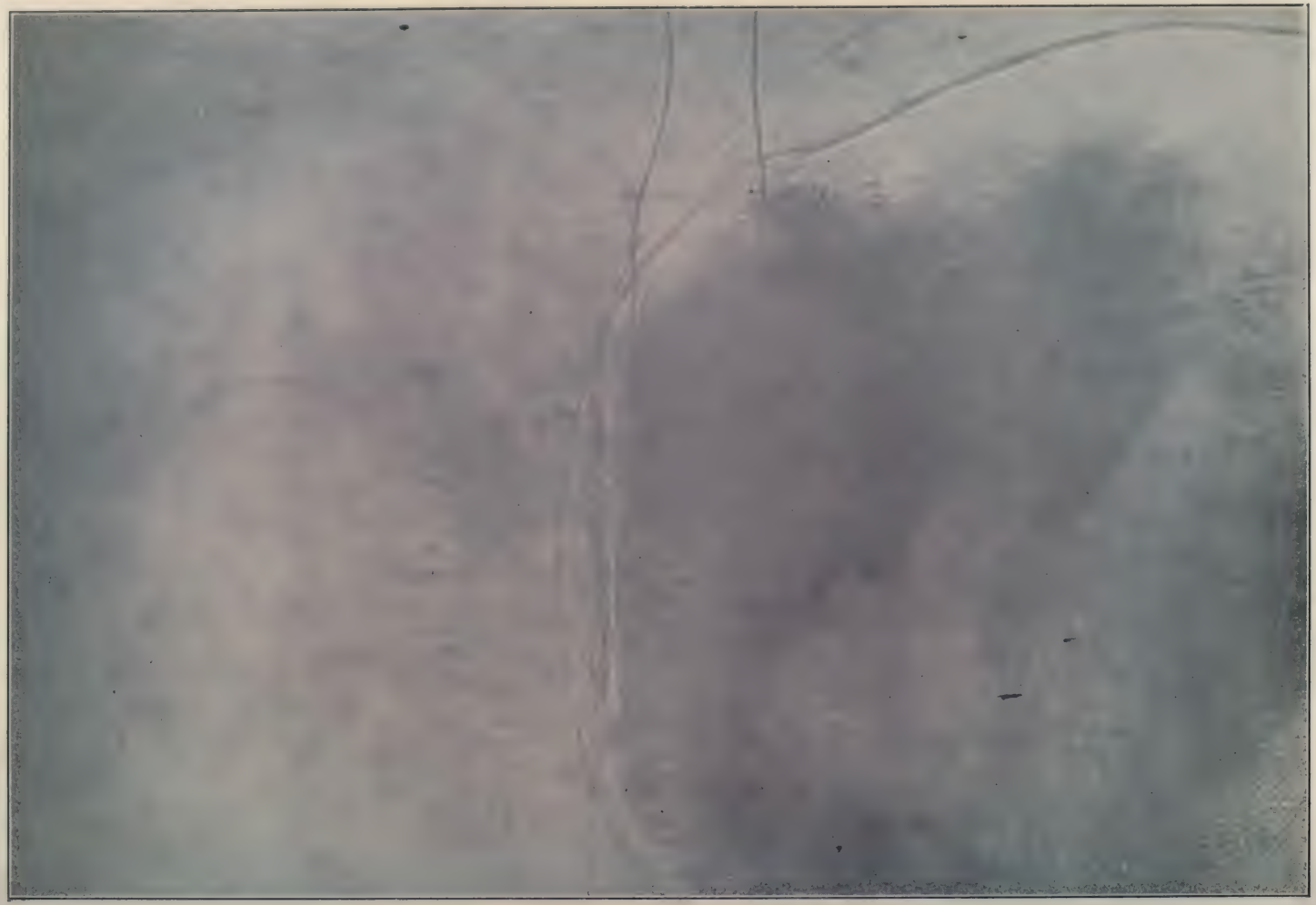


FIG. 1. PHOTO I. Without Silencer and directly at muzzle.

GUN REPORT NOISE

ACTION OF THE MAXIM SILENCER AND THE DIFFERENCE BETWEEN REPORT NOISE AND BULLET FLIGHT NOISE EXPLAINED

BY HIRAM PERCY MAXIM

When a gun is discharged it is the common idea that there is a single noise heard, the report noise. That such is not the case, and that there are two entirely separate and distinct noises has been proved in a very interesting manner by the advent of the Maxim Silencer. The history of the research work which led up to this device is very instructive and well worth recording.

When the work was undertaken at the beginning, the object was to annul report noise so that concealment of position, partly attained by smokeless powder, would be completed. When the firing line became invisible, there was only left the report noise to indicate its position and also its strength, or number of guns.

To attain this object, it was thought only necessary to check the suddenness of the release of the high pressure powder gases into the atmosphere. This pressure, in the calibre 30 U. S. Service Springfield rifle, was approximately 10,000 pounds per square inch, when the base of the bullet emerged from the barrel muzzle. A device must be found which would present an unobstructed path for the bullet, but this path must not be available to the gas, at least easily.

The search for a path which would give a bullet an absolutely unimpaired passage, and yet would check gas at 10,000 pounds pressure per square inch, was a long one. For a year it persisted without results. Its successful ending came in a very interesting though extremely prosaic manner. The essential element was a hole which would be pervious to a rifle bullet, but impervious to high pressure gas. One morning, after taking a bath and pulling the plug in the tub drain hole, the water was given an accidental twist and the familiar little whirlpool was created. It attracted the eye and finally the mind, since there was a hole through which water was passing but slowly, notwithstanding the fact that the drain plug was removed. In a flash the analogy was apparent. It was obvious that centrifugal force prevented the water from passing through the hole rapidly. If the powder gases in a gun were given the same vigorous whirling action, they would also acquire centrifugal force, and, if their outlet hole were located at or approximately at the center, they would exit relatively gradually. They simply could not exit until they had slowed down at least a little. The search was ended.

A little gas whirling device was quickly made, and adjusted to the barrel of a rifle and the first shot fired was the first quiet rifle shot ever discharged from a high power rifle.

When shooting was done in several different places, it began to be apparent that the noise depended upon the place, at least when a high power rifle was used. It seemed to be impossible to eliminate a certain sharp "crack." The character of this crack was similar to a whiplash crack. It was entirely different from the more dull boom of the report. By accident it was found one day that this "crack" noise existed a long way down the range. A listener located at the 500-yard mark on a 1,000-yard range, detected the crack noise apparently overhead. This indicated immediately that it was connected with the bullet flight in some manner and was en-

FIG. 2. PHOTO J Without Silencer, about 4″ from muzzle.

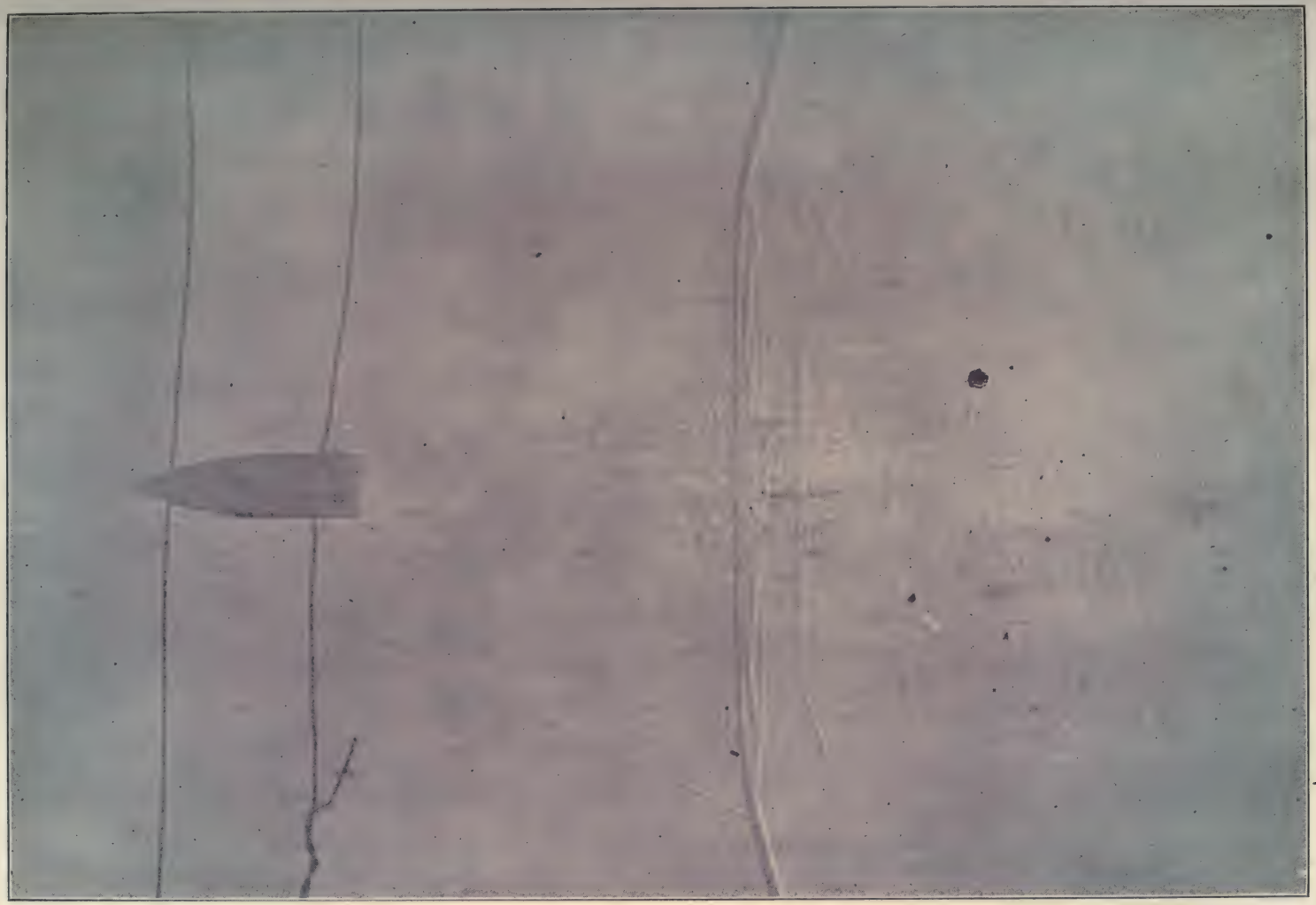


FIG. 3. PHOTO N. Without Silencer and about 8″ from muzzle. Note little grains burning smokeless powder, each creating small bow wave of its own.

tirely separate and apart from the report noise.

Tests were made to bring out additional facts, and some of these are instructive. It was suspected that the bullet flight created a bow wave, creating a little zone of compressed air which moved out from the trajectory, and that this wave was heard by reflection. The person shooting the gun always heard a different noise from the person located at a distant point down the range. A terrain was selected on the extensive meadows on the Connecticut River bank below Hartford, where a series of clumps of bushes and small trees existed. There were three separate clumps in front of which the bullet from a Springfield service rifle could be made to pass. When the gun was fired, the listener at the gun heard three separate sharp cracks, and a low rattle of many minor cracks. This pointed fairly conclusively to the fact that the bow wave was reflected back from each of these clumps and separate noises were heard from each because they were separated by enough distance to give a distinguishable interval.

It was then thought that firing down a railroad track which ran along the open meadow, and had telegraph poles at regular intervals, would give a good test. This was done and the result was a rapid succession of cracks, just as had been anticipated.

Then it occurred to the writer that if he could find a place to shoot where there would be no object from which reflection could occur, he ought to secure quiet shooting. It seemed a difficult condition to find until he bethought himself of getting up on a knoll away from trees and other objects and shooting straight up into the air. There would be no objects up in the air to reflect back the bow wave and if the theory were correct, such shooting should be almost entirely quiet. It was with much interest that a suitable place was searched out. One was finally found and the first firings were felt to be of great moment. The first shot told the story, for the only noise was the puff of gas from the Silencer which sounded very soft and low. There was absolutely no bullet flight sound heard. The bow wave went on and on and never returned.

The next thing was to locate the limits of this bullet flight noise. It evidently persisted in certain guns while in others it never occurred, while in still others it occasionally occurred. Bullets from various cartridges were fired and it very soon developed that when the bullet velocity reached the velocity of a sound wave, the crack became noticeable. When the bullet velocity fell below the velocity of sound, there was no crack noise. The velocity of sound then appeared to be the critical point above which the ordinary bullet could never be fired quietly. It developed that the .22 calibre smokeless cartridges, except in the case of the long, gave quiet shooting, because their velocity was below 1,085 feet per second. The long cartridge appeared in some cases to be above this velocity though not always. There was evidently un-uniformity. The long rifle cartridge was always beautifully quiet, as was of course also the short cartridge. The 22 W. R. F. cartridge, which is a special high power, seemed to be just on the critical line. For example, in a box of fifty cartridges, about half would shoot without bullet flight noise, whereas the other half would make a loud crack. With all the larger calibre regular cartridges, bullet flight noise occurred. By using special loads, they all gave quiet shooting. In some cases very heavy bullets were used and the striking energy maintained in spite of the lower velocity. The reduced velocity of course reduced the distance at which accurate shooting could be accomplished. Two hundred yards always was possible, however, with bullet velocity of 1,000 feet per second, which is well inside of the critical point.

Before the question was considered settled, it was thought necessary to make various shaped bullets. Some were made of approximately perfect stream line shape. Others were made with a central hole all the way through the bullet. A copper gas check was used over the base when firing, and this fell off as soon as a

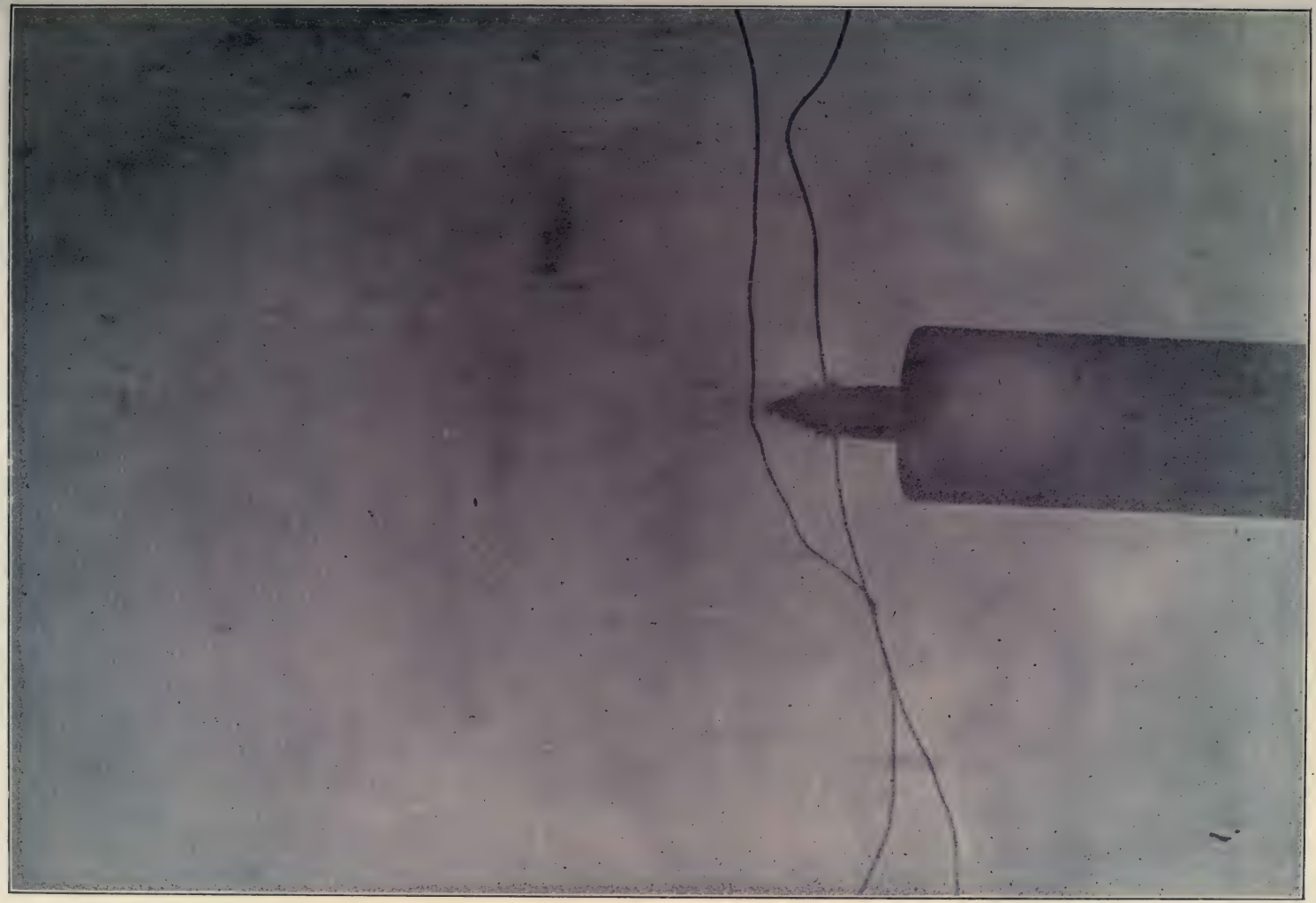


FIG. 4. PHOTO A. With Silencer, and directly at muzzle.

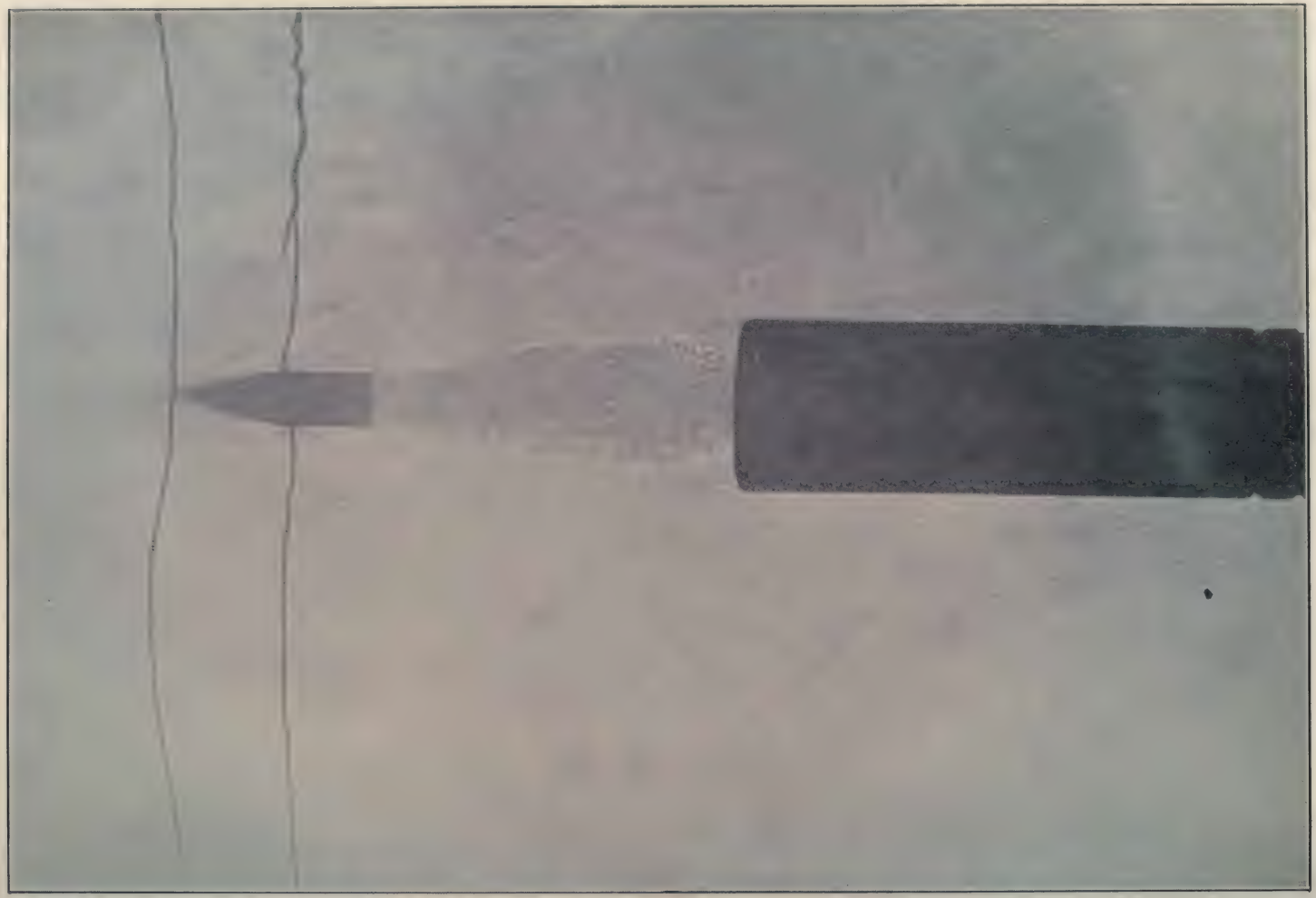


FIG. 5. PHOTO B. With Silencer, about 2″ from muzzle. Silencer is 1″ diam., bullet is ″.300 diam.

bullet left the gun barrel. There never was a single piece of evidence upon which to hang a theory that the noise was in the slightest degree altered.

Then came the desire to actually see this peculiar manifestation, and, incidentally, to conclusively prove the Silencer. It was always a bit difficult to prove to the ordinary mind that the noise heard when shooting a rifle equipped with a Silencer was made out in the air beyond the Silencer, and that the latter should not be held accountable.

The United States Navy, through their Ordnance Department, produced the best photographs which have been taken. These were made by mounting the gun in a dark room and setting up the camera with an open shutter along the line of bullet flight. Two wires leading from an electric condenser were dropped down directly beside the trajectory so that the bullet would short circuit these wires when it passed, and create a spark, the duration of which was of radio frequency, possibly something approximately one five hundred thousandths of a second. This almost infinitely short exposure gave a clear photograph of the bullet and the variation in density of the air in the bow wave caused a variation in the refraction of the light, causing less light to fall where the pressure was high and more light where the pressure was low. Beautiful pictures of the noises made when the gun is discharged were obtained. Some of these are shown herewith. A series were taken showing the noises when the service rifle without Silencer was fired and another series with the Silencer. In the former, the report noise is shown, the birth of the bullet flight noise, and the bullet itself. In the latter the entire absence of report noise is shown and the very high efficiency of the Silencer demonstrated.

Fig. 1. (Photo I) Represents the condition existing immediately following the emerging of the bullet at the muzzle of the Springfield rifle without Silencer. The two vertical wires are shown and the bullet is enveloped in the mass of powder gases, and cannot be seen. The first wave appears to be made from a rush of air out of the muzzle and the main report noise wave is shown just back of it, being the broad dark line, irregular in places.

Fig. 2. (Photo J) Represents conditions just a bit later. The bullet was emerged from a cloud of powder gases, and has just begun the creation of its bow wave. It is shown puncturing the main report noise which shows particularly strong in this picture. By looking carefully, the noise waves set up by flying particles of unburned smokeless powder can be seen.

Fig. 3. (Photo N) Represents conditions still later, and out beyond the disturbance of the blast of gas from the muzzle. The bullet flight bow wave has developed farther and the greater velocity of the bullet over the report noise wave is very well shown. It is not plain at this time why the main report wave should be divided at the rear of the bullet. This completes the series of photographs taken without Silencer.

Fig. 4. (Photo A) Represents the first picture with Silencer on the rifle. The bullet is shown emerging from the muzzle of the Silencer, the bow wave of bullet flight noise is shown and there is absolutely no sign of any report noise. Indeed there seems to be no disturbance created at all except the bow wave from the bullet.

Fig. 5. (Photo B) Represents the conditions just a bit later. The bow wave and also a stern wave from the bullet is shown, the discharge from the Silencer, but absolutely no report wave.

Fig. 6. (Photo E) Represents a still later period, the bow wave being distinctly shown, and the wake of the bullet. The stern wave has begun to disappear, for what reason it is not quite plain.

Fig. 7. (Photo F) Represents a still later time and the wake of the bullet is the principle point of interest. This seems to partake of a spiral motion. The bow wave and the remnants of the stern wave are shown but no report wave.

Having now shown the conditions existing at the muzzle of a firearm, equipped with a Maxim Silencer, and proving as conclusively as seems possible that the

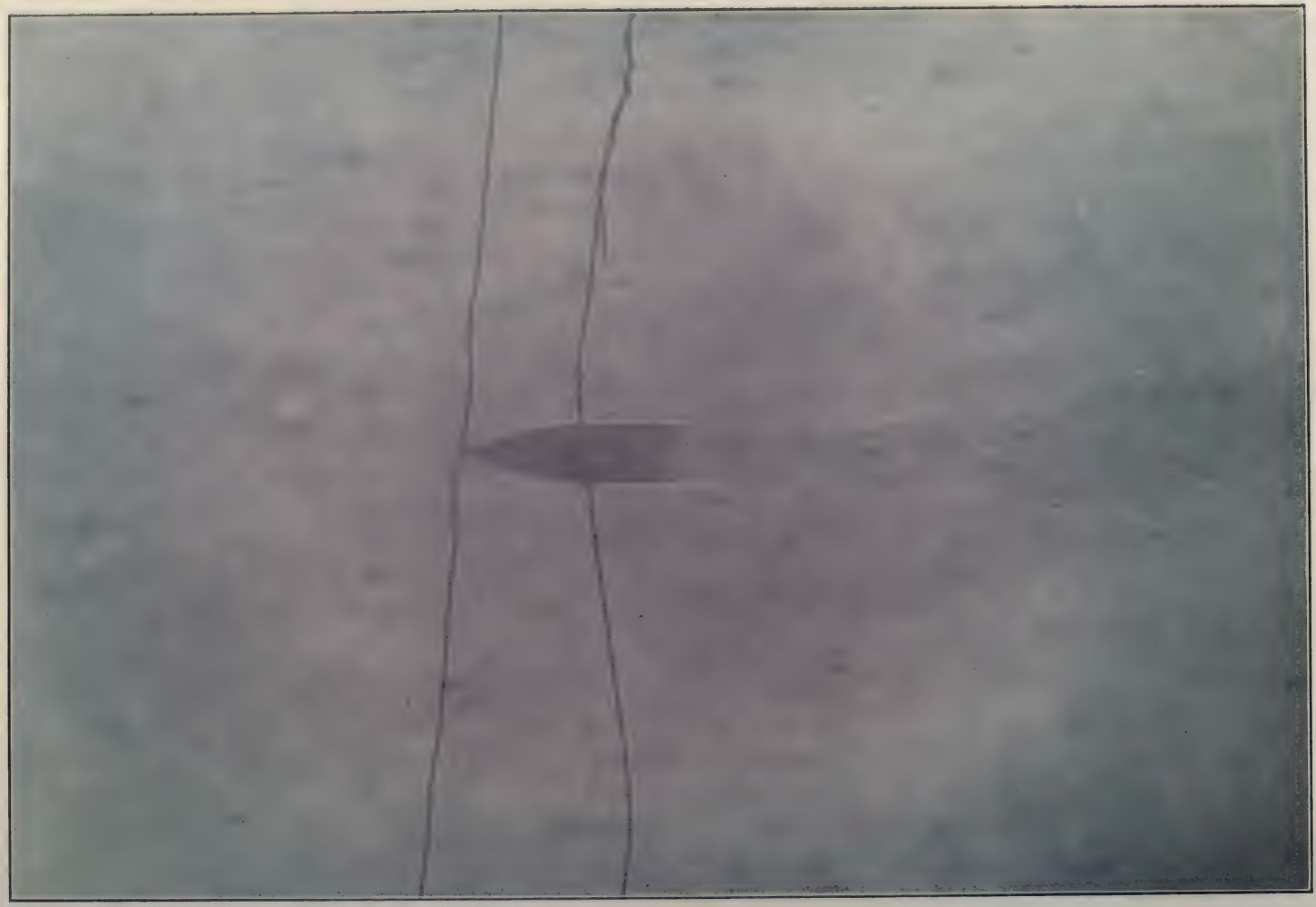


FIG. 6. PHOTO E. With Silencer, about 6″ from muzzle.

FIG. 7. PHOTO F. With Silencer, about 8″ from muzzle.

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noise of the gun is eliminated and that the only noise remaining is the bullet flight, we may ask the practical results. These have been very carefully studied from every imaginable angle. Field tests, accuracy tests and tests at night have been conducted officially by War Departments with bodies of troops equipped with Silencers. Briefly summarized, these amount to the following:

1. The most important advantage on a shoulder rifle seems to be the diminution of sound on one's own firing line, which permits officers' commands to be heard during periods of the most rapid and concentrated fire. Without the Silencer the human voice cannot be heard.

2. The concealment of position of the firing line and the concealment of the number of guns comprising it. This is a natural advantage which might be imagined.

3. Improvement in marksmanship because of reducing the tendency to flinch. The elimination of the conclusion entirely and the reduction of the recoil by 50 per cent. makes the modern military rifle a much more gentle gun, and the rank and file in innumerable military tests always make higher scores than with the bare rifle.

4. Elimination of muzzle flash at night makes location of the shooter invisible. This is supposed to constitute an important military advantage.

The aspects of a quiet shooting firearm in the case of assassins is of interest. We have seen that we cannot secure quiet shooting unless we have bullet velocity below 1,085 feet per second. Except in 22 cal., this requires specially loaded cartridges for all calibres. Furthermore, the Silencer, being a gas check device purely and simply, and applicable only to the muzzle, the ordinary revolver cannot be silenced because of the joint between the cylinder and the barrel allowing the gas to escape if it is checked at the muzzle by the Silencer. Thus the assassin's favorite arm is unsilenceable, to coin a word.

In the case of the automatic pistol, it is almost an impossibility to attach the Silencer, and moreover the almost instantaneous opening of the breech permits a back blow and usually upsets the ejection of the empty shell enough to cause a jam. So, we cannot expect to see the automatic pistol silenced, as things stand today. The assassin will have to design a small arm with a breech mechanism constructed on the lines of a rifle if he is to take advantage of any silencing device. Such a weapon does not exist at the present time.

Thus, we have the story of one man's study of the noise that occurs at the muzzle of a firearm.

THE SCIENTIFIC WORK AT WOODS HOLE

GREAT VALUE OF THE UNUSUAL LABORATORY FACILITIES OF THE MARINE BIOLOGICAL LABORATORY TO THE STUDY OF THIS BRANCH OF SCIENCE

BY CAROLINE CHASE BIGELOW

THE scientific work carried on at Woods Hole has now become a factor of so great importance in all biological study that it is worth while to consider the scope at the present day in order to appreciate the growth from the simple pioneer work of forty odd years ago. In 1871, Spencer Fullerton Baird founded the government station; in 1888, a little group of men and women established a small private laboratory, selecting Woods Hole where the sea water is exceptionally pure, where the strong tide of the Hole keeps the water in a condition healthful for biological research, where no rivers decrease the salinity of the water, and where no large cities pollute the waters with sewage. From these early days of simplicity down to the present time, there exists a course of development in marine biological research which has touched many sciences, and contributed enormously to human knowledge. The extensive number of laboratory buildings, and the great number of scientists, many of world reputation, who visit Woods Hole each year, are strong evidences of the value of Woods Hole investigation at the present day.

Since the little Massachusetts seashore town first came to scientific notice the two institutions have been synonymous with the place. While absolutely separate in organization and maintenance, as well as somewhat diverse in purpose, the great subject of marine life cannot fail to link them in spirit. The Laboratory of the Bureau of Fisheries, maintained by the Department of Commerce, has the culture of fish for its aim, while the Marine Biological Laboratory, a private corporation, devotes its attention to abstract research and instruction; the one is commercial, practical; the other academic, "science for science's sake."

The Bureau of Fisheries has a small staff of permanent scientific men, and employs, in addition, each summer fifteen or twenty experienced investigators from various colleges. In the early days, these men thoroughly considered the conditions about Woods Hole, with the result that the rich marine life there is now more fully known than in any other region of similar extent on the Atlantic coast, temperatures, salinity, tides, currents, bottoms, fauna, etc., having been all most carefully studied. Then as the bureau turned to fish culture, primarily because of its decided commercial value, numberless problems presented themselves to the investigators. As the increase or decrease in the numbers of fishes about our coasts may be due to a great variety of causes, and may be controlled by an equally large number of factors, we find the government investigators studying the chemical conditions of waters in which the fish live, the environment, the foods, the plant life, the habits of each species, the nurture of the very young, the distribution, the diseases, the enemies. To quote a report of the Department of Commerce, referring to Woods Hole: "The information necessary as a basis for the conservation and improvement of the fisheries, therefore, covers a wide field in aquatic biology, physics and chemistry, and the scientific work of the bureau is governed by an appreciation of these requirements."

Recent or current inquiries include the study of oysters and clams, their food and oxygen requirements, the investiga-

tion of fishery by-products, water pollution as affecting economic animals, lack of resemblance between young and adult forms, as the flatfish. Furthermore, the work of the laboratory in winter is devoted almost entirely to the hatching of young fish to repopulate the coast waters, and in the year 1913–14 the station hatched and planted 182,000,000 cod, 373,000,000 flounder, and 2,500,000 mackerel. Besides this work which has a commercial character, the laboratory seeks also to foster pure science and welcomes, each year, qualified investigators who work on more abstract problems of marine biology, or men whose work along kindred lines may be advanced by the consideration of marine material. As an arrangement has existed from earliest times between the laboratory and various universities, whereby the latter may each appoint an investigator to a research table in return for money given towards building the laboratory, there are every year at the Fisheries, a few investigators and graduate students pursuing their lines of work apart from any problem suggested by the bureau. Connected with the laboratory are adequate craft for collecting material at various depths, fish traps, and an enclosed basin for the preserving of large living specimens. In years past, before the waters about Woods Hole were as carefully surveyed as now, excursions were made on well known boats such as the *Fish Hawk* or the *Albatross* for dredging and collecting in the Gulf Stream, the *Albatross* in 1883 making one of the early deep sea dredges on a trip from Woods Hole. Collecting trips are now principally confined to search for material needed by investigators.

The Marine Biological Laboratory, the neighbor of the Bureau of Fisheries, was founded in 1888, for the purpose, to quote from its own act of incorporation, "of establishing and maintaining a laboratory or station for scientific study and investigation, and a school for instruction in biology and natural history." In the early days, the character of the laboratory was of the very simplest; now, thanks to the generosity of Mr. Charles R. Crane, president of the corporation, the laboratory has recently acquired a large fireproof building, designed especially for research, and equipped with every known improvement. This gift has done much to raise the standard of the equipment to a level commensurable with the grade of work done within its walls. The laboratory has, first of all, a large and able group of investigators who pursue their own problems, and publish many of their results under the auspices of the organization. Second to them are a group of "beginning investigators," graduate students and the like who are pursuing their own problems under the experienced guidance of the older men. As nearly forty institutions now subscribe to research tables and rooms at the Marine Biological Laboratory, thus securing the privilege of appointing a man for summer work, the influence of the laboratory is becoming far reaching in the collegiate world. Lastly, the laboratory maintains a summer school (six weeks in time) offering courses in zoölogy, embryology, physiology, botany, and the philosophical aspects of biology and allied sciences. Members of the research staff, augmented by other gentlemen, give the instruction in these subjects.

The investigation covers, of course, all the field of marine biology, and the application which such work might have to any other science. The splendid new laboratory, with pure running water from the sea, chemical room, physiological room, balance room, a considerable outfit of physiological apparatus, a most adequate supply department for the collection of living material, all render the conditions admirable for serious work. Apart from the marine work, some investigators are pursuing other lines of biological research, choosing Woods Hole as a working place because of the laboratory facilities, and the inspiring influence of research enthusiasm. Such men as E. B. Wilson, T. H. Morgan, E. G. Conklin, Jaques Loeb, G. N. Calkins and H. E. Crampton have stamped their personality upon the staff of the laboratory. The instruction is planned largely for

Buildings of the Bureau of Fisheries at Woods Hole. From left to right: the laboratory, the power house, the residence. In the background may be seen the mess and the homestead of the Marine Biological Laboratory.

those having a professional interest in the subjects, supplementing college or university courses. Fundamental vital phenomena, shown to particular advantage in sea animals and plants, is considered, and stress laid especially upon living material. The opportunities to study development, or animal behavior as a living process in so wide a range of forms is unique, and the benefit of actually observing and of forming a conception of these phases cannot be overestimated. Encouragement is given to students interested in special lines of work, as preparatory to future research or to a profession. Lastly, the work in philosophy is offered to meet "a growing demand for a working out of the more general presuppositions, implications, and interpretations of the methods and results of biological investigation."

This, in brief, is the outline of the work carried on at Woods Hole. To appreciate the charm of the place, the lure of research, the fascination of living matter, one must participate, or at least be an intimate observer. Here the professor may work out his own absorbing problem amid peaceful surroundings, relieved from the cares of classes and administration, yet surrounded by equipment as fine as that of his own laboratory. Here the graduate student may start in on research, preparing for any scientific career, in an atmosphere where enthusiasm has gathered all the workers together. Here the undergraduate may add to his college curriculum a course

which can only be given in summer when living material is plentiful, and store up for himself, meanwhile, the wholesome vigor gained by a summer vacation in a simple seashore town. Looking back over the history of Woods Hole, the words of Mr. Crane, at the opening of the new laboratory, seem most pertinent: "We have come here to celebrate the wonderful spirit that is back of the Marine Biological Laboratory. It is very difficult to define that spirit, but I think we all know something of it, and something is also known all through the scientific world. Without that spirit, no amount of bricks and mortar and organization would be of great service, but with that spirit the laboratory has been able to accomplish a very great deal, with very simple means."

TWIN TREES

An unusual example of grafting is seen in two elms (*Ulmus americanus*) growing near Cortland in central New York. They stand upon a bluff overlooking Brown's gorge and are far from any dwelling. The trees are twenty feet apart at their base and unite at a height of twenty-five feet above the ground. That the union of the trees is physiologic as well as superficial is shown by the enlargement of the combined trunk immediately beyond the point where they meet. The smaller tree is fourteen inches in diameter at its base, the larger eighteen inches, both normally decrease in diameter to the point of union, immediately above which the trunk enlarges to a diameter considerably greater than immediately beneath, from which it again tapers normally. This tree reaches a height of about seventy feet. The roots of the smaller tree are partially uprooted on the side farthest from the larger one and the uppermost of these roots have long been rotted away leaving mere stumps. This early uprooting, and hence probably also the grafting, was evidently the work of a wind storm, though it is a common belief of the countryside that the grafting was the work of the former Indian inhabitants.

H. W. S.

SOUTHERN HEMISPHERE COLDER

Dr. G. C. Simpson, the British meteorologist, believes that the southern hemisphere is much colder than the northern hemisphere, the reason being that while on the northern hemisphere there are large masses of land to take the sun's energy and give heat to the air, in the southern hemisphere there is much more ice, which is practically a perfect reflector, returning into space the solar energy falling upon it. Dr. Simpson thinks that five million square miles of the earth's surface in the southern hemisphere returns the heat of the sun, and this is one of the chief reasons for the difference in the temperature between the two hemispheres.

Owing to the high price of aluminum a California power company is substituting copper wire at an appreciable profit.

NATURE'S UNITY OF PHYSIOLOGICAL PLAN

Animals are those organisms whose most fundamental characteristic is movement. They vary in size from microscopic forms to the whale, and in complexity from the one-celled protozoön, in which all bodily functions are performed by this one cell without organs, to the vertebrate whose body is composed of millions of cells arranged into many organs for the performance of the bodily functions. Throughout, however, this immense diversity of size and complexity there exists one unity of physiological plan. The simplest organism has the same fundamental bodily needs as the most complex and hence performs the same physiological functions with its far simpler mechanism. In the common necessities of digestion, respiration, etc., the protozoön is at one with all life up to man.

All animals must alike procure food, swallow and digest it; the digested portion must be carried to all parts of the body for its repair and upbuilding; at the same time the worn-out portions must be carried out of the body. All animals must move and breathe, and sense the presence of food or things objectionable.

These common needs and their expression in the same physiological functions may be indicated in a comparison between the comparatively highly developed snail and man, who crowns the evolving line of animal life. Both make the food fine before swallowing it so that it may be digested the more readily, the former by means of a file-like tongue, the radula, the latter by teeth. Digestion, or chemical disintegration of the food into a condition in which it may pass through the walls of the digestive canal into the blood vessels, is performed alike by both; this is done largely in the anterior portion of the digestive canal, the stomach, while the posterior part, the long intestine, gives opportunity for the blood vessels to absorb all good food, the undigested remnant passing out of the canal as solid waste. In both the mollusk and man, closed tubes, blood vessels, carry this food mingled with the blood to all parts of the body, and a heart helps to force it along more perfectly. As the blood gives up this food for the repair and upbuilding of the body it gathers up the broken down cells and other body waste, which it gives up to the kidneys through which it passes before reaching the heart; these glands throw it out of the body. Besides passing through the kidneys the blood similarly upon each circuit of the body passes through an organ where the gaseous requirements (oxygen) of the body may be procured and the gaseous waste (carbon dioxide) thrown out. This organ is called a gill when the oxygen is taken from the air enclosed between the molecules of water, and a lung when the oxygen is taken directly from the air. The gill in the mollusk is an outpocketing of the mantle, a thin fleshy fold surrounding the compact body and lining the shell. The blood pouring into the blood vessels lining these minute pockets is separated from the water by a thin moist membrane through which the waste gas, carbon dioxide, brought by the blood from all parts of the body, can easily pass by osmosis and the needed oxygen enter. In man the lung is an outpocketing of the throat, but since a moist membrane is necessary for the osmotic interchange of these gases the lungs become of necessity enclosed within the body; the air is taken into these much-divided outpocketings and finds all the surrounding walls penetrated by a network of blood vessels, through which the interchange readily takes place.

To control the exact performance of these complicated functions as well as to perform the complex movements necessitated by the desires of the organism, a multitude of nerves, like telegraph wires, extend to every part of the body. In the mollusk these are much more poorly centralized than in man. In the former the principal centers are a couple of enlargements, ganglia, in a nerve ring around the

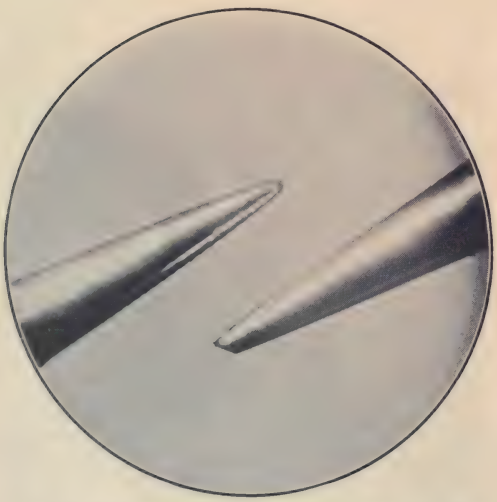
throat; these are connected with a ganglia in the foot and with one in the digestive region of the body. The mollusk may thus be said to have a diffused brain.

In man the nervous system is well centralized, most messages being sent to the brain or to its posterior prolongation, the spinal cord. In both organisms, however, despite the vastly differing complexity of the mechanism, the fundamental need of movement is performed by muscles controlled by nerves and the fundamental processes of digestion, respiration, etc., are performed by organs of similar fundamental plan, controlled in each case by sets of nerves and ganglia.

Man possesses no more sense organs than do most mollusks though here again there is an immeasurable difference in complexity and power of perception.

Such a comparison enforces the realization on the one hand of the oneness of all beings in nature, and on the other of the mighty force of evolution in bringing the complex from the simple, the highly developed from the primitive.

HERVEY W. SHIMER.



Above is a much enlarged photograph of two phonograph needles, a new one and one that has been used to play one Wagner record. The phonograph companies are making extensive research to find a material from which needles can be made that will not require frequent renewals.

CAUSE OF BANANA DISEASE

Among the theses presented by the graduates of the Institute of Technology last year was one on the study of the life cycle of a fusarium and the effects of certain fungicides upon it. A fusarium is a parasitic fungus which causes destruction by producing dry rot in potatoes and causing scab diseases in various plants. One of the most recently discovered plant diseases produced by these fungi is the so-called Panama disease of the banana which, in a little more than ten years, has spread along the country bordering on the Atlantic from Mexico to Brazil. Although it is now certain that fusarium is the cause of this disease, the life history of the organism, that is, its mode of growth and its spore formation, is not entirely clear. The object of the author, Mr. Peter Masucci, has been to determine its life cycle and to find a poison that will kill the fungus.

The speaker described the technique of cultivating the fungus from a single spore, and spoke of the experiments with different kinds of toxic agents. There are three ways of combating such a plague: By prevention in the killing of the parasites before they reach their hosts; by cure of the diseased plants; and third, by preventing the spread of the disease through the use of infected implements by some sort of aseptic method. The investigation touched the first and third of these processes.

It was found that the ordinary fungicides here lose their virtue for the reason that the organic matter in the soil combines with them and makes them useless as poisons. Phenol and creosote have under these conditions but slight germicidal action. Bleaching powder, however, has proved to be fairly effective.

With regard to the disinfecting of freight cars, tools and other implements used in the plant industry, all of which are known to carry disease, Mr. Masucci finds that bleaching powder is here far more effective than formaldehyde or lime-sulphur. Its use can probably be relied upon to check the spread of disease through any of these channels.

From Magnus sive de Arte Magnetica (1643)

TARANTISM AND THE DANCING MANIA

Some people, in an effort to explain the modern dancing craze, have attempted to liken it to the remarkable dancing mania of the Middle Ages. Whether this is true or not, it is interesting to recall to mind the extensive outbreak of frenzied dancing which swept over a great part of Europe, particularly during and immediately after the tremendous epidemics of the Black Death. One of the earliest outbreaks to be completely described occurred in Aix-La-Chapelle in 1374. The following strange spectacle was noted: Men and women "formed circles hand in hand, and, appearing to have lost control of their senses, continued dancing, regardless of the bystanders, for hours together in wild delirium, until at length they fell on the ground in a state of exhaustion. During the paroxysms the victims had hallucinations and some asserted that they felt that they had been immersed in a stream of blood, which obliged them to leap so high."

This extraordinary disease rapidly spread to many parts of Belgium, Holland and Germany, where it was variously known as St. John's or St. Vitus' dance, according to the saint who was supposed to protect those afflicted. The malady was first considered the work of the devil and the clergy were kept busy in their efforts to exorcise the evil one. That the disease was contagious was obvious and the victims were prone to acute recurrences.

In Italy, where the disease later appeared, the learned Nicholas Perotti, in an account of the disorder, points out that no one had the least doubt that it was caused by the bite of the tarantula, a common ground spider, particularly plentiful in Apulia, a southern district in Italy. It is significant to note this early attempt to explain the malady on natural lines and subordinate the supernatural. From the insect the disease was given the name of *tarantism*. There was a general conviction that by music and dancing the poison of the tarantula was distributed throughout the whole body, and expelled in the sweat induced by the great exercise. Later on it became evident that even those who were not bitten contracted the disease. Inquisitive persons who came to see the unfortunates in their wild dances not infrequently stayed to participate. Relief could only be obtained by dancing until complete exhaustion was produced. The musicians, who in some instances were employed by the municipality for this special purpose, were under no circumstances allowed to stop and substitutes had to be employed to relieve musicians who were themselves literally played out. As time went on it was noted that special kinds of music were very effective in bringing about the speediest cures. Music which permitted quick lively dancing was most efficacious. A rapid music imported from Turkey soon became the standby and was given the name of tarantella, a term still used to describe a rapid whirling dance. The accompanying illustration taken from Athanasius Kircher's *Magnes sive de Arte Magnetica* (1643) shows the tarantula, a map of that portion of Italy first affected and a few stanzas of music labelled *Antidotum Tarantulæ*.

Tarantism was at its greatest height in Italy in the seventeenth century, long after the disease had disappeared in Germany. From this time the disease decreased but has appeared on occasion among special sects as for example the Convulsionnaires in France, the Holy Jumpers and the Barkers in England, the Holy Rollers in the United States.

Space prohibits a discussion of the disease itself, suffice to say that it is definitely known to be a nervous disorder akin to an imitative hysteria. It is doutbful if we shall ever see such widespread affections, but we may expect occasional outbursts of a similar character in connection with fervent revival services and the like. The poor physical and mental condition of the people in the past produced through poverty, plague and other disasters undoubtedly played no small part in preparing their minds for the disorder of the Dancing Mania.

S. M. G.

SCIENCE CONSPECTUS

VOL. VI 1916 No. 3

THE PLAINS OF NORTHWESTERN CANADA

STORY OF THE VARIED GEOLOGICAL CHANGES THAT HAVE CO-ACTED TO PRODUCE THESE VAST TREELESS PLAINS AND GREAT ALLUVIAL BASINS

BY D. B. DOWLING

THE plains of Canada form but a portion of the larger plains of the continent, which occupy a large part of the interior and are divided into an eastern and a western portion by a great central valley. The eastern plains which extend to the St. Lawrence lowlands are forested and, therefore, are seldom referred to as plains. Westward, the rainfall being lighter, there is a thinning of the forests and there are more open areas. These are generally referred to as the plains. In Canada the open prairie of the plains is being invaded by the forests from the north, so that a division can be made of treeless plains, plains with scattered trees, and forested plains.

The first requisite in a definition for these plains would perhaps be, a nearly level surface supplemented by a soil covering and a climate admitting of the production of some vegetation, for the absence of moisture soon produces desert conditions. The formation of a level surface, to take a homely example, suggests either *planing* or *plastering*. The planing process of nature is a slow decay of the old surface and its removal by erosion. The surface thus planed is inclined to be rocky and, as it is losing its rock waste, the soil is to be found sparingly in the hollows or valleys. In plastering, the nature process consists of the spreading out generally by large bodies of water of the rock waste poured in by the streams. This produces a more perfectly even surface outline than is ever produced by the planing process, but our surface features are the product of both. If the surface were a part of a perfectly rigid sphere it would be difficult to explain the presence of large areas containing the rock waste or of those plains built up by the spreading action of the sea, but, as there is a vast amount of evidence showing that the continent has not been stable but sank in certain areas, rose in others, and repeated the sinking and rising several times, we are forced to believe that the crust is flexible and that its equilibrium is influenced by tangential strains or the shifting of load. To this we owe the submergence of those parts which received a coating of rock waste deposited by the sea. Much of this rock waste underlies the great agricultural areas or plains so that we may say that the flexibility of the crust made possible the peopling of the earth by providing soil covered areas for the plant growth necessary to support the animal life. The plains of North America bear in their underlying rocks the record of long invasions of the sea and these form a part of the history of a continent which seems to have been a very old feature.

Much of its early history is very

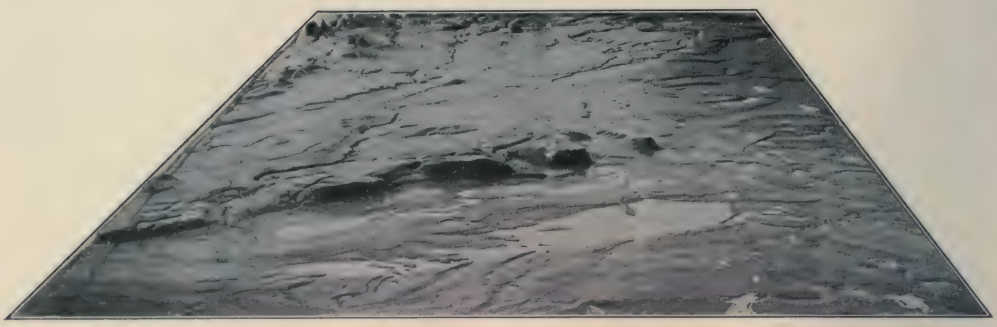


FIG. 1. The Manitoba Lowland and The Plains, a representation of the surface on an exaggerated vertical scale, looking west. Lake Winnipeg in the foreground

obscure but we know that at several periods the ocean encroached and almost submerged the continent. The maximum submergence was probably in Ordovician times when much of the limestone deposits of the continent were formed. Later, the seas seemed to have been shallower and the rocks, formed by the débris entering the sea, were of a fragmental character and became better soil makers. The plains of eastern America owe most of their fertility to the decay of these rocks, but the western plains, now called the Great Plains, received still further treatment beneath a shallow muddy sea which covered the sandstones and limestones of the former plain by a heavy coating of mud now hardened to shale. Then when the sea invasion was about over, the great mud flats supported a very rich vegetation which is preserved in coal seams. The later additions to the building of the plains consist of coarser material and indicate a nearer source of supply which means an elevation of the land underlying and adjoining the western edge of the basin. With the draining away of the salt water there was an additional elevation in the land area which amounted to mountain building. This consisted of the formation of folds as a partial relief from the tangential strain, but as the movement continued probably too rap-

FIG. 2. Diagrams showing Cretaceous basin and its elevation by tangential stresses

idly for the material to follow without fracture, most of the folds became broken.

We thus find, as a typical structure in the Rocky Mountains, fault blocks piled one against the other in regular succession, repeating the same series of beds many times. In front of the broken area or to the east of it, folds and breaks of less intensity and lower elevation occur at present and towards the east the decreasing disturbance in the rocks show very clearly that the strain was from the west. The formation of the Rocky Mountains is about coincident with the elevation of the plains, for in their slow rise the soft rocks forming the covering of the broken folds were washed down and carried across the plains by the streams or spread out in lakes. On the completion of the first period of erosion, after the appearance of the outer mountains, the plains presented probably a rather rough, rock strewn surface on the higher slopes. The removal of much of this débris was made possible only by a further elevation and with a steepening

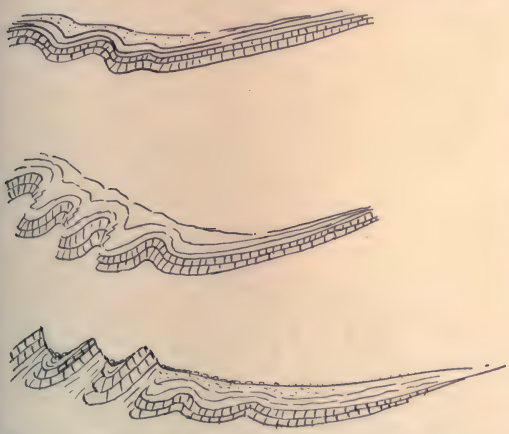


Fig. 3. Removal of broken material reveals mountain structure

of the slope eastward the second scoring began. This was continued until from the surface hundreds of feet were removed. The cycle of denudation was not completed, as is shown by remnants of the first surface which still remain.

The coming of the ice sheet of the glacial period is thought to have altered the general topography but little, with the exception perhaps of a smoothing of the uneven surface or a filling up of sharply cut valleys. The period during which the ice was wasting or melting is marked by many drainage channels that are now abandoned. The occupation by the glacier of the valleys of the prin-

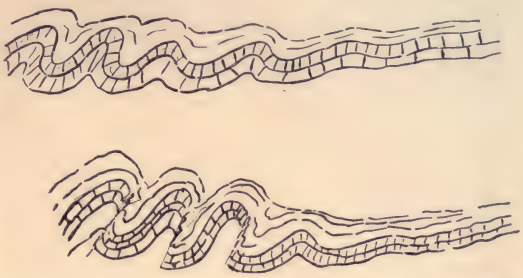


Fig. 4. Continuation of folding to the breaking point

cipal streams which have a northeastward trend caused no doubt a damming up of the water which, together with that from the melting ice, overflowed along the ice front and sought channels that were almost at right angles to the original channel. Many of these are still used as parts of the present river courses, but in the southern portion of the Canadian plains there are many of these glacially induced channels that are now abandoned and have apparently no other reason for their existence. The Saskatchewan drainage was diverted to the Missouri for a short period while its former valley through the Coteau was blocked by ice. The diversion filled Lakes Chaplin and Johnston and proceeded south, scouring out the valley now occupied by Lake of the Rivers, Willowbunch and Big Muddy Lakes. A little later the outlet was shifted to east of the Coteau and the Regina plain was a lake basin drained by the Souris River probably to the Red River valley. This lake was lowered by the retreat of the ice to a position farther north and a new channel was again adopted. This was deeply cut by the flowing streams and is now used by the Q' Appelle and Assiniboine Rivers which have but a small flow at present.

FIG. 5. Diversion of Saskatchewan River. Illustrating one stage of the retreating ice front across the plains. (Note—Modern names and railway could not be deleted)

The melting of the ice in the lowlands of the Red River valley created a lake along its front of the ice that was not as readily drained as was the case in the retreat of the ice cap across the prairies. In the Red River valley there seemed no outlet and the basin filled until it spilled over its lowest point, far south in Minnesota at Lake Traverse. The removal by melting, of a vast mass of ice in the north, seems to have resulted in a slight elevation of the crust that had been depressed by the weight of the ice. This recovery which means an actual tipping of the lake basin lowered the lake by spilling its water to the south and as the lake at its several stages formed beaches, the levels of these give us the amount of tilt that occurred between their dates of formation. This outlet was abandoned when the lake secured a lower northern outlet. The greatest depth of water over the site of the city of Winnipeg was about 560 feet.

The benefit of this old lake to the agricultural value of the Red River valley can hardly be measured. Over the surface of the boulder clay, which covered the limestone outcrops, the waters of the lake spread a thick coating of the finely ground shale that was excavated in the digging of the several large valleys that cut through the plateau to the west. This deposit in lessening amount or thickness is found over the lake basin area north of the Red River valley and underlies the plains around Dauphin, Swan and Red Deer Lakes.

On account of the soft nature of the rocks the stream valleys are deeply incised which adds to the difficulty of using this passing water on the upland where it is often needed since the rainfall is barely sufficient during some seasons to make up for the evaporation. Were these rivers nearer the surface the question of diversion would be simple but long and expensive canals are required. The surface is generally treeless owing to the light rainfall. Tree planting is

FIG. 6. Manitoba Lake Basin showing present lake levels with outline of beaches at higher stages (Lake Agassiz)

proceeding rapidly and is quite noticeable in Manitoba where the bare prairie is rapidly disappearing. This, if it does not induce a much greater rainfall, retards the evaporation of the ground moisture.

As a short summary we may repeat that the basin, which received the muddy deposits of Cretaceous time, has had a varied history. The rocks of the western margin were elevated and broken into long narrow blocks which are piled up in succession to form the Rocky Mountains. A second strip was strongly folded but not elevated as high as the mountains and constitutes the foothills. A third strip formed a ridge in advance of the folded foothills and now shows a simple synclinal structure, while the remainder, less disturbed but sloping generally to the east, forms the Great Plains of the northwest provinces.

UNUSUAL LIGHTING EFFECTS

UNUSUAL lighting effects were features of the spectacular masque and pageant given in connection with the dedication of the new buildings of the Massachusetts Institute of Technology. Thirty-four 1,000-watt stereopticon projectors fitted with nitrogen-filled lamps were installed at intervals of 3 feet 3 inches on the roof of one of the buildings for the purpose of flood-lighting and spot-light effects, while a similar arrangement was installed on the roof of a facing building. There were four 1,000-watt projectors, each in a pit with a glass cover, for securing lighting effects in the central ring, and four 250-watt units, also in glass-covered pits, for illuminating jets of water used in connection with the water dances.

SAFE CANDY

HOW FEDERAL FOOD SUPERVISION AND THE INVESTIGATIONS OF SANITARIANS HAVE RAISED THE STANDARD OF THE PRODUCTS OF THE CANDY INDUSTRY

BY S. C. PRESCOTT

THIS is the candy age. Candy in some form is found in practically every household. Gifts of candy are made by hundreds of thousands and appear to be ever acceptable. It would be difficult to estimate with any degree of accuracy the number of tons of sweets which pass from retailer to consumer during the holiday season. Some of it has been of the highest grade, some of lower commercial quality, but it has all added to the enjoyment of the season. Each year candy becomes more and more contributory not merely to the holiday period, but to the enjoyment of life at all times and places. The candy or confectionery industry has in ten years nearly doubled and in twenty years has developed from an insignificant position into one ranking easily in the first score in the value of the output and number of hands employed.

In Massachusetts, for example, confectionery ranks fifteenth among the industries of the state in the value of the product and there are employed in the candy factories in this state alone over six thousand persons. Thus the industry has developed not merely into a permanent and important one, but one liable to still further marked increase, for while candies must still be regarded to a great extent as luxuries, their consumption is constantly increasing among all classes of people. Because of its importance it is apparent, therefore, that the industry should really be grouped among the food industries.

Of the usefulness of good candies there can be no question. Despite the early prevailing opinion that all candies were unwholesome, caused digestive disturbances, and were primary causes in the decay of the teeth, it is now recognized that good candies are high in food value, entirely wholesome if used in moderation, are no more predisposing causes of decay of teeth than other carbohydrate foods, and supply to the body *energy* in large amounts and in quickly available form. In other words, here is a *special food* which we may still regard as a semi-luxury but which, none the less, does bring to the consumer a marked amount of available energy as well as the pleasure derived from its consumption. In fact the craving for sweets which is sometimes manifested not only in children but also in adults should be regarded as a perfectly normal demand of the body for a certain class of carbohydrate foods and not an unhealthy appetite, and it has been suggested that when this craving is satisfied, others, as for example for alcohol, disappear or are greatly lessened. Assuming, therefore, that candies are to be regarded as special types of foods, even if not absolutely essential types, the position should be taken that they, like all other manufactured foods, should be subjected to such processes of inspection and treatment as will *guarantee the quality of the raw materials, safeguard the hygienic or sanitary character and maintain the high food value conditions of the product.*

As with other commodities a great range of products may be obtained, varying from the very expensive and attractive in appearance to the very cheap and unattractive; from the high-class goods produced under good sanitary conditions to those which have little to recommend

them either from the standpoint of quality or cleanliness in production and handling.

This great development in the scope of the business has been made possible partly because of the study which has been given to the manufacturing, but particularly because the scope of raw materials entering into the composition of these candies has been greatly increased. Thus the use of corn syrup, chocolate, dried and evaporated milk, eggs, albumen, gelatin, and the great variety of fruit and nut products, have made it possible to secure the great variety of products which we have at our disposal, and it may be emphasized that their use is absolutely unobjectionable so long as they are pure, clean and wholesome.

The importance of the industry from the standpoint of *public health* is, however, quite as noteworthy as its commercial importance. With the constant increase in consumption we must demand safe candy. Here is an industry in which the product passes directly and sometimes quickly from the hands of the worker in the factory to the mouth of the consumer. Public welfare demands that the greatest care should be taken that all *substances* used in the manufacture of these products should be free from objection from the hygienic standpoint, that the *processes* should be carried out under sanitary conditions and with every attempt to prevent contamination, and that the *employees* should be under such strict supervision that there can be no possibility of infection by undesirable bacteria of these materials which go directly without cooking into the mouths of the consumers.

From very early times sweet products have been highly regarded, and candy making was apparently an accomplishment practiced by some of the Romans, who had booths along the Appian way for the sale of their alluring products. That they were not always of the highest quality would seem to be evident from the statement of Cicero who somewhere alludes to "the filth and reeking sickness" produced by their consumption (or abuse?), and who suggests the need for some control of their preparation so that it would be possible to "seek out those doing harm and put punishment on their heads." Evidently the need for sanitary inspection of materials or processes was acute, and a portion of the candied products was not "safe."

It may be pertinent to inquire what "safe" candy is. Primarily it is that which will do no harm to the consumer. This means that the ingredients contain no poisonous chemical substance, and that there is not lurking within an attractive exterior the living germs of disease.

A candy may be "safe" and still be inexpensive. Just as we must recognize commercial grades in fruits, or in tea, or coffee, or in eggs or in a thousand other commodities, we must also recognize commercial grades in candy. If Mr. X. can retail chocolates at forty cents while Mr. Y. charges eighty cents a pound, there is obviously likely to be a difference in the commercial values of the materials used, or in the skill used in making, or the way in which the package is presented to the consuming public. But either one of these products may be "safe." One may be quite as wholesome as the other without having the same attractiveness. On the other hand, it is possible that neither might be "safe," although on this point the chances are fortunately very small.

With the working of the food laws, and care taken by the large dealers of excellent reputation who produce a very large percentage of the candy sold, dangers from adulteration with dangerous chemical substances is extremely uncommon. From this standpoint most candy is "safe."

This fact, however, is not as widely accepted at present as it should be. Within a year there appeared in large headlines on the front page of a Boston paper the announcement that several children had died as a result of eating poisonous candy. The article went on to say that this candy had produced "aci-

dosis," and that chemical examinations of some of the candy had shown the presence of a "powerful acid" in the candy. Of course those who are familiar with the manufacture of candy at once said: "Impossible, this cannot be true." "The statement is the result of the disordered imagination of a reporter." But what of those who did not know of what materials candy is made? In twenty-four hours or even less, the report that candy had been the cause of the deaths was denied. There was no real evidence against candy at all, although the actual cause has not been elucidated. If the children ate Christmas candy it was probably safe candy, unless it had become contaminated from the fingers of some one who had handled it.

The contamination of food materials may be brought about by one of several different methods or by combination of them. The raw materials themselves may be objectionable, for example, certain of the materials used in candy may contain salts of arsenic, zinc or lead, sulphur dioxide, formaldehyde, or other substances which are prejudicial to health. As a matter of fact, the candies manufactured by reputable dealers do not contain these substances. In the second place, contamination may take place from dust infection due to dirt blown in from the street, dust from floors, and it is conceivable that such germs as diphtheria bacillus and tubercle bacillus might gain entrance in this way. Here again the observed facts are strongly against the probabilities of such an occurrence. In high class candy factories care is taken in regard to the ventilation and also in regard to the floors, as obviously dust gaining entrance to the goods brings about objectionable discoloration and renders the product less attractive and appetizing. In the third place, contamination of candy might result through the handling by operatives who are suffering from various kinds of disease but in which the disease has not reached such an advanced stage as to be apparent. It is from this source that danger is to be apprehended and it is on this point that the greatest care is demanded of the manufacturer. From what we know of "carriers" at the present time it is unquestionably true that those who handle our food substances in any way may subject it to a certain amount of contamination.

The chief way in which candy may be rendered unsafe is by the contact with polluted fingers of the occasional disease "carrier." Suppose a chocolate dipper had typhoid last summer, or it may be years ago, and became a "carrier." She might appear in the best of health and yet daily produce typhoid bacilli in large numbers, which without an unusual lack of personal cleanliness could in part find their way to the chocolates. The probability of such carrier infection is slight. No case has yet been reported, but if manufacturers are wise they will exclude from dipping or packing rooms all persons who have had typhoid and who have not been proved by medical examination to be not a carrier. As carriers give away their germs by contact, it might happen that other workers near by, especially if close friends, might be infected. This source of danger could be largely eliminated by requiring that those handling foods should be vaccinated against typhoid. In fact this treatment is to be recommended to all in any case as a safeguard against a dangerous disease which is all too prevalent in America.

In some experiments carried out in my laboratory with my former student and associate, Mr. E. H. Cummins, we found that typhoid bacilli would survive in chocolate for long periods of time, although the numbers were greatly reduced. For example, we found in a chocolate containing 4 per cent. of water and to which 400,000 bacilli per gram were added, that only 24,000, or 6 per cent. survived after 140 days. In a chocolate containing 8 per cent. water we put an average of 260,000 per gram. At the end of 40 days 15,000, or about 6 per cent., remained alive. In a chocolate containing 29 per cent. water the initial number in-

troduced was 200,000 per gram. Here, after 225 days, typhoid bacilli were still found in considerable numbers. The most interesting thing revealed by this particular test was that in forty-eight hours the number was almost as small as after 225 days, indicating that a large percentage would die on the first few days in case of an infection such as I have imagined.

Our work has, on the other hand, also had some most reassuring results in the study of the survival of other kinds of bacteria, for we found the bacillus of tuberculosis to disappear in a very few hours, as did also other germs.

It is probably fair to assume that it is only rarely that a heavy infection would take place in the handling of candy, but it is well for the manufacturer to be keenly alive to any opportunity, however remote, by which his product could be the means of distributing disease.

From the foregoing statements it should be apparent that the candy industry as a branch of the greater food industry is on the whole, in a very satisfactory condition. The larger dealers, and they manufacture the preponderant percentage of the candy sold, have found it of advantage to maintain conditions of cleanliness and to have a strict regard for the purity of their raw materials. The results of tests by introducing bacteria into candy are also reassuring since they indicate that it is only the occasional type of germ which will survive for any extended period, other forms quickly disappearing owing to the lack of suitable nutrition. All of the high class candy may therefore be regarded practically as "safe candy" providing it is not subject to dust infection and to unlimited handling by people of unclean habits.

The exposure of penny goods in nooks along the street and other places where wind can bring about wholesale dust infection from the ground-up material from the street must be regarded as objectionable and dangerous. Similarly, the manufacture of candies in ill-lighted basements where no attention whatever is paid to sanitary supervision either of apparatus or operatives must be looked upon with distrust. Agencies which are at work within the industry will undoubtedly very largely remove these objectionable features. Furthermore, the coöperation which is constantly extending between the operatives and the employer in the matter of welfare work, conditions of labor, hygienic supervision, provision for rest rooms, proper toilet facilities and other agencies of cleanliness, and in many instances visiting nurses and physicians, are constantly raising the standard of the products of the industry. On the whole, it would probably be difficult to point out any branch of the food industries where the improvement had been greater and where the product goes to the consumer with a higher degree of protection.

FOUR-DIMENSIONAL VISTAS

In the introduction to his book "Four-Dimensional Vistas," Mr. Claude Bragdon says: There are two notable emancipations of the mind from the tyranny of mere appearances that have received scant attention save from mathematicians and theoretical physicists.

In 1823 Bolyai declared with regard to Euclid's so-called axiom of parallels, "I will draw two lines through a given point, both of which will be parallel to a given line." The drawing of these lines led to the concept of the curvature of space, and this to the idea of *higher* space.

The recently developed Theory of Relativity has compelled the revision of the time concept as used in classical physics. One result of this has been to introduce the notion of *curved* time.

These two ideas, of curved time and higher space, by their very nature are bound to profoundly modify human thought. They loosen the bonds within which advancing knowledge has increasingly labored, they lighten the dark abysses of consciousness, they reconcile the discoveries of western workers with the inspirations of eastern dreamers; but best of all, they open vistas, they offer "glimpses that may make us less forlorn."

FLIGHT IN ANIMALS

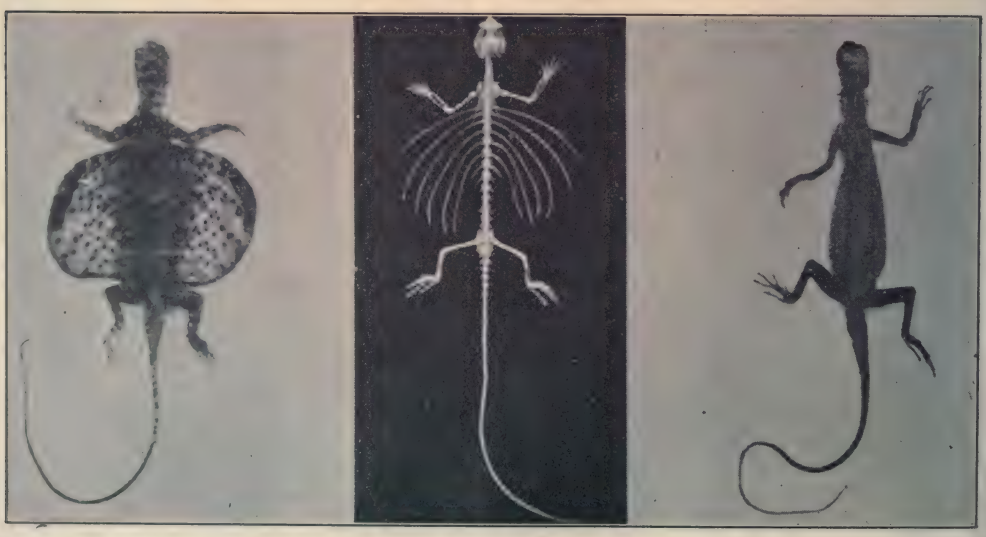
A BRIEF SURVEY OF THE HISTORY OF GLIDING AND TRUE FLIGHT IN ANIMALS—EVERY CLASS OF VERTEBRATES HAS HAD FLYING REPRESENTATIVES

BY H. W. SHIMER

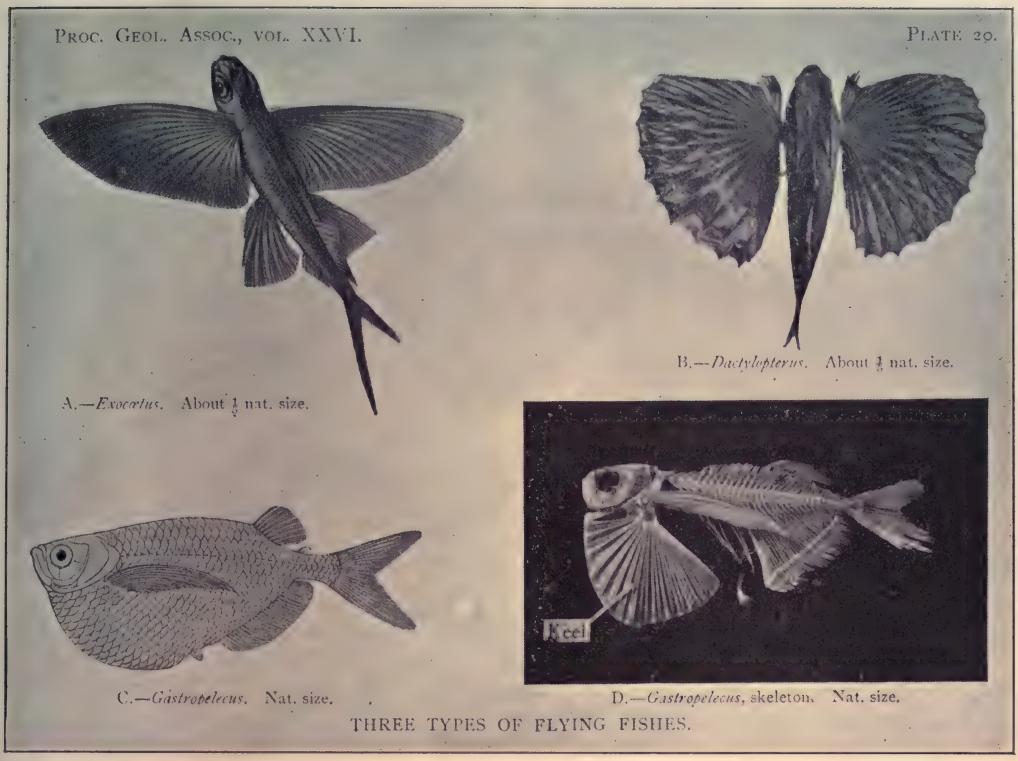
THE art of flying is a late development upon our earth. First acquired in the late Paleozoic by the insects, it apparently did not appear among animals with a back bone until the succeeding era, the Mesozoic. Animals as well as plants first acquired the ability to live in water; later, as the waters became crowded, the land was invaded, and it was but natural that when these two realms became densely populated, representatives of the highest groups of animals—insects and vertebrates, should seek food and safety in the air.

Flight among insects has been wonderfully successful. Since, however, their peculiar mechanism limits them to small forms they are entirely at the mercy of heavy winds and hence can not compete with the heavier and more muscular vertebrates.

It is noteworthy that every class of the latest animal phylum to appear upon this earth, the vertebrates, has flying representatives. Of course the art varies enormously in the fish, amphibians, reptiles, birds and mammals. Some are merely gliders; others are true fliers. The typical gliding membrane, the patagium, consists of a double fold of skin extending along the sides of the body connecting to a greater or less degree the fore and hind limbs and at times also the tail. This skin acting like a parachute enables the animal to glide through the air without muscular effort and usually only in a downward direction. Fliers are able to sustain themselves in air by



Draco Spilopterus—1. Patagium expanded. 2. Skeleton showing elongated ribs. 3. Patagium closed



THREE TYPES OF FLYING FISHES.

muscular effort and alter their direction or altitude at will. True flight is confined to birds, bats and the extinct flying reptiles, the pterodactyls.

Since fish breathe by gills they cannot leave the water long and have hence developed few flying representatives. The flying organs of fishes are usually the very much enlarged pectoral fins. In some species of Exocoetus the fish may continue 300 yards at a uniform height of a foot or so above the water. The well known Catalina flying-fish (Exocoetus californicus) reaches a length of 18 inches.

The present day Amphibia are the insignificant remnants of the class which ruled the land during the later Paleozoic. Transitional as they are from a water to a land life it is not strange that no fossil flying forms and but a single living form are known. In the tree-dwelling "Flying Frog of Borneo" the feet are very large, with webs extending to the tips of the toes. With feet outstretched it is able to make great gliding leaps from tree to tree.

The comparatively few living reptiles which can fly belong to the gliding type. Draco, the Flying Dragon of the Malay Peninsula and Pacific Islands, of which there are some twenty species, is a small arboreal animal about a foot in complete length. In Draco the patagium is supported by six very long ribs.

During the Mesozoic era of earth history, however, reptiles possessing the power of true flight were very numerous. These had large membranous wings consisting of a double fold of skin stretching from the sides of the body to the ends of the greatly elongated fore limbs. That these extinct animals were good fliers is shown by the fact that, like birds, many bones are hollow, the skull is large and light, the breast bone is flattened and their fossil remains are frequently found in deposits estimated one hundred miles from the nearest land.

In birds the flight apparatus is entirely

unique, and has proved wonderfully successful. Instead of a patagium there are specially developed feathers borne upon the fore limbs, the air beating organs. Since microscopically these feathers consist of interlocking hooklets and ridges, the resultant is a very efficient, though light, apparatus for striking the air. The earliest birds, appearing in the Mesozoic, possessed sharp teeth and a long vertebrated tail with a pair of feathers attached to each vertebra; gradually, however, the teeth disappeared and the long tail became shorter and shorter until among living birds it consists of some six small vertebrae and a vertical terminal bone; this last represents a fusion of several vertebrae and around it the tail feathers are arranged in a semicircle. This enables the bird to become lighter in weight without interfering with the efficiency of the tail as a rudder.

Among the eleven living orders of the class of mammals at least four possess members capable of some measure of flight. Of the four, marsupials, rodents, insectivores and bats, only the last are true fliers; the others are merely gliders. In all, unlike birds, the flying or gliding organ is a patagium, a double fold of skin upon each side of the body between fore and hind limbs.

In the marsupials this power is limited to the arboreal family of phalangers. These flying forms, confined to the Australian region, have the patagium extending down to wrist and ankle. They vary in size from that of a small mouse to a length of 20 inches from snout to root of tail.

In rodents, gliding is confined to the members of two allied families, the African flying squirrels and the true flying squirrels. Of the latter, one species occurs in the United States, the rest are confined to the Old World and are almost restricted to the Indo-Malayan region. They vary in length of body, exclusive of tail, from 5 inches to 12 inches. The patagium usually extends to wrist and ankle.

The order Insectivora possesses only the so-called Flying Lemur,—Galeopithecus; one species confined to the Malay Peninsula and Pacific Islands, the other to the Philippine Islands. In these the patagium is very large, extending to the tips of the toes and the end of the tail.

Pteranodon occidentalis—Span of wings 18 to 20 feet

In bats, the only true flying mammals, the patagium embraces limbs and tail, and is especially extended over the greatly lengthened fingers of the hand to produce an efficient organ for beating the air. The skeleton is very lightly built and the breast bone, as in birds, has a keel for the attachment of the wing-muscles. Bats represent a successful mammalian off-shoot, as they are found all over the world and even within the Arctic circle. They vary in size up to a spread of wing, in the Flying Fox of Java, of 5 feet. They occur fossil from early Tertiary (Upper Eocene) to the present.

Aside from the insects, Nature's first

Hesperornis regalis—Height about 3 feet

Ichthyornis victor—Height 10 inches

experiments in flight appear to have been in the early Mesozoic among the fish. Forms with enlarged pectoral fins, the typical flight organ of fish, were developed independently in different families, at intervals from the Triassic to the present. Among the reptiles and mammals the patagium is the flight organ. From the primitive form seen in the Flying Gecko where the patagium is merely a fringe of skin extending along the sides of the body, limbs and tail, through the flying phalangers and squirrels where these fringes are enlarged to form broad expansions between fore and hind limbs, to the much enlarged condition in the flying lemur, Galeopithecus, flight occurs with body held rigid. If the animal acquired the habit of jerking or waving its limbs during flight, modification of these limbs might take place and a true wing be produced. This has occurred independently among the reptiles in the pterodactyls and among the mammals in the bats; the former made their first appearance in the early Mesozoic disappearing with its largest members in the late Mesozoic; the latter appeared in the

Patagium-wing of Bat, showing enlargement of four fingers

early Tertiary, their largest representatives living today. Birds were contemporaneous with the pterodactyls but were not numerous until the early Tertiary after the disappearance of the latter. It is interesting to note that while the early representatives of flying reptiles, birds and bats had a long vertebrated tail, this had disappeared completely in the later pterodactyls and in bats, while in birds its place is taken by the fan-like tail feathers. Apparently a long tail as a steering organ is not a necessity. Another parallelism is seen in the gradual disappearance of teeth and the development of a beak in both pterodactyls and birds; whether this change will also occur in the bats of the future it is impossible to say.

(The above is largely a review of "The Geological History of Flying Vertebrates," by George W. Young, in the *Proceedings of the Geologists Association*, Vol. 26, pp. 229–265, 1915, London; to which we are also indebted for the figures.)

SELF-DIRECTION IN EVOLUTION

Self direction of activity and consequent control of environment become greater and greater from lower to higher forms of life. The protozoön slowly gropes, or darts blindly, hither and thither in search of food. The sluggish clam collects such edibles as happen to come within the reach of his suction pump. The tiger, with every muscle tense, ever ready for the final rapid leap, slowly creeps upon his prey. In man, active thought before deliberate rapid action is developed to an ever higher and higher degree. The higher protozoöns and the Saint Vitus dance victim both have physical activity highly developed, but in both, self direction of these actions is slight. Bodily inaction in man no more necessarily denotes active thought than does similar inactivity in the clam.

In the development of life upon this earth, we note a similar advance in organic activity from the early pre-Cambrian eras, through the Paleozoic and Mesozoic to the present Cenozoic era of earth history. The little we know of life in the time of the pre-Cambrian shows that it consisted of such low types as algæ among plants and protozoöns, sponges, etc., among animals, organisms with activity but slightly self-directed and almost entirely controlled by environment.

With the incoming of fish and of the primitive ancestors of the squid and devilfish in the lower Paleozoic there occurred a decided advance in this connection; for these animals, with nerve centers concentrated into brains and with organs for rapid locomotion, could sense both food and danger at a distance and were thus enabled to change their environment to suit the needs of the moment. That is, environment had ceased to exercise so complete a control over their lives.

With earth's waters thus ruled by such highly developed animals, evolution shifted to the land, and there appeared in the Upper Paleozoic the amphibians, transitional from water dwellers to land dwellers, and next such typical land animals as the reptiles. This land life advanced still further during the Mesozoic for with the development of the earliest birds and mammals the highest classes of animal life were reached though not its highest expression, as these early species were the most primitive of their kind. It was in the Cenozoic, the present era of earth history, that these higher types evolved, finally culminating in the highest mammal, man. The amphibians, reptiles, birds, mammals and man form an advancing series in self-direction of activity and in a greater and greater independence of environment. In each class there is a similar advance from the primitive representatives, those appearing earlier upon the earth to the later appearing, more advanced types.

Thus organic life has developed from activity directed and controlled by environment to activity self-directed, the organisms understanding environment to an ever greater and greater degree and hence, to that extent, becoming independent of it.

HERVEY W. SHIMER

METHODS OF STUDYING COAL

HOW A NEW METHOD OF REFINED TECHNIQUE HAS REVEALED PLANT RECORDS TO THE INVESTIGATOR, ESPECIALLY WITH REFERENCE TO THE ORIGIN OF COAL

BY E. C. JEFFREY

Coal, since it is a mineral, has in the past been investigated with the aid of the admirable technical processes, which have been devised by the mineralogist and petrologist in the study of minerals and rocks. Fossil plants, also, have naturally been regarded as minerals, since in the condition ordinarily studied structurally they are petrified: that is, infiltrated or, in some instances, actually replaced by mineral substances. In addition to the relatively scanty petrified remains of fossil plants, which have previously been the most important document for the student of extinct vegetations, there are huge quantities of plants of former epochs, preserved for us by a more or less complete process of carbonization. This carbonization is so marked in some instances, that it is obvious that the plant remains have been charred previous to fossilization. The present writer has turned his attention to the utilization of these carbonized remains, in connection with the tracing of the all too incomplete geological records of plants. By the perfecting of processes of softening and bleaching these carbonized remains, it has been found possible to add very largely to our knowledge of the organization of ancient plants, particularly of the Mesozoic Age, concerning which our information has been most meager. Methods developed first for the investigation of isolated members and parts of plants, by modification have proved serviceable in the study of that structurally almost unknown mineral coal. Our ignorance of the organization of coal is not due at all to the neglect of mineralogists, but rather to the unsuitability of the approved methods of their science in the case of a substance at once so opaque and so friable. The advantages of the methods recorded here may be judged from the fact that they permit the cutting of large quantities of sections, which average one tenth of the thickness of the few and laboriously secured preparations resulting from the grinding processes of the mineralogist. Moreover it is possible to render the sections even more favorable for study by bleaching, which is inapplicable to ground sections. It should be added that the successful manipulation of the processes described in the subsequent paragraphs involves a considerable experience in the use of the microtome, the slicing mechanism of the biologist.

The more recent and less modified coals are treated for sectioning with comparative ease. Alcohol alone is frequently sufficient to bring about the necessary degree of softening for successful slicing. Such coals are of relatively light hue, and sections need not be so thin as is essential in the case of the older and more highly carbonized coals. In general, however, somewhat vigorous softening agents must be used in the investigation of combustible minerals, since pressure and temperature have often brought about a considerable degree of modification even in coals of tertiary and secondary origin. Caustic soda or potash dissolved in alcohol of about 70 per cent. strength in the proportion one part in ten is a very useful preliminary reagent but has been found for various

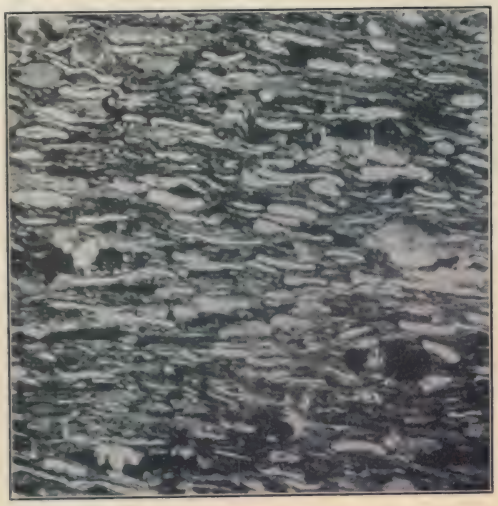


FIG. 1. Cannel Coal from Ohio, showing quantities of spores (light) and small fragments of highly modified wood (gray)

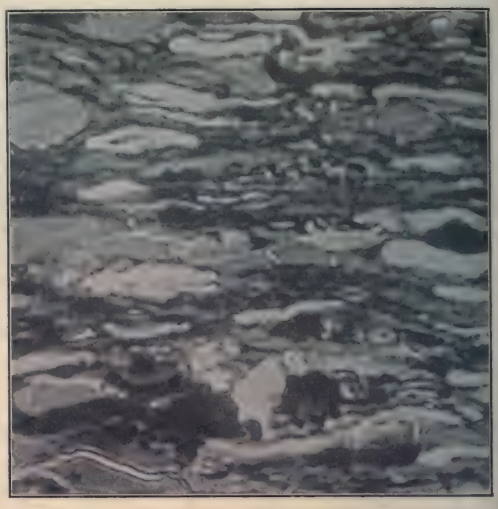


FIG. 2. Cannel Coal, upper left hand region of (1) more highly magnified, showing spores (light) and modified wood (gray)

reasons, less valuable in use than phenol. This substance has unfortunately advanced immeasurably in cost on account of its employment as a basis for the manufacture of high explosives in the present European war. The phenol or carbolic acid is melted and the selected coal samples (which must ordinarily not be more than a centimeter in length and breadth by half a centimeter in thickness vertically) are subjected to its action. The material is to be kept hot in a water bath for a number of days, usually as long as a week. The carbolic acid is then washed out with repeated changes of warm water. Heat and subsequent treatment with water after neutralization by means of an acid are likewise necessary in the case of material treated with alkaline alcohol, as described above. The advantages of the use of phenol in softening coal are that less swelling and cracking results than in the case of alkaline alcohol, and the material is in better condition for subsequent manipulations.

The removal of mineral substances from the coal is the next stage and for this purpose hydrofluoric acid is most generally employed. The fragments of coal remain in strongest commercial hydrofluoric acid for some days or even a week or more. In the case of coals neither much carbonized nor possessing a very high proportion of ash, the processes indicated suffice. In most coals, particularly those of the Paleozoic period, after treatment with hydrofluoric acid, the combustibles must be washed for a day or two in running water and then returned to the phenol for a renewed sojourn in the heat. This second softening in many cases is sufficient, but where a higher degree of carbonization is present, a second treatment with hydrofluoric acid is needed. In still more resistant coals the processes must be further repeated and the acid is reinforced in its action by adding crystals of chlorate of potash or soda, which brings into play the activity of nascent chlorine. With anthracites and other coals of an extreme degree of carbonization, nitric acid may be added with advantage to the hydrofluoric acid and chlorate of potash, but in moderation so that maceration may not result. The treatment with hydrofluoric acid and accompanying reagents, where these are necessary in the case of more refractory coals, is carried on in wax bottles or in glass bottles coated both

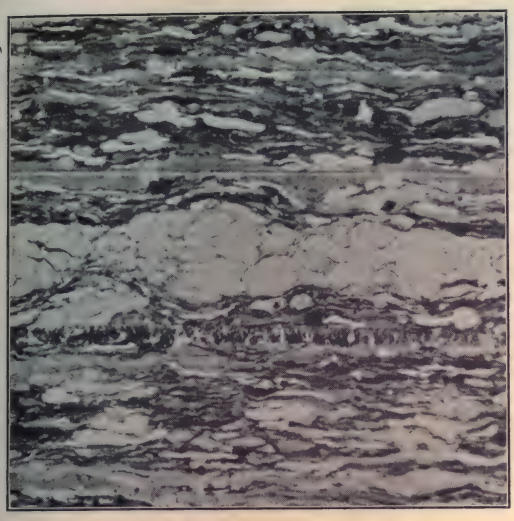


FIG. 3. Bituminous Coal, Lancashire, England, showing numerous spores (light) and more abundant modified woody material (gray)

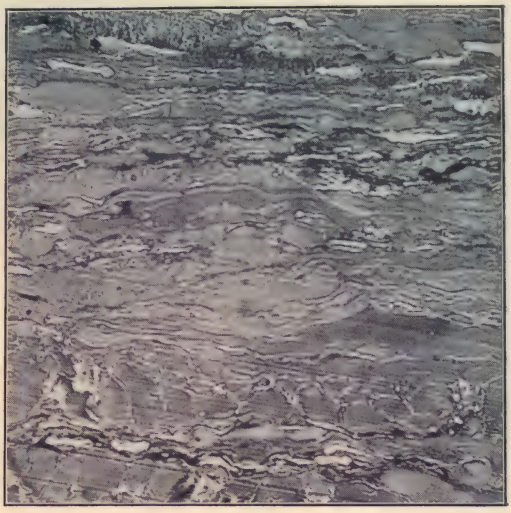


FIG. 4. Bituminous Coal, Hocking Valley, Ohio, showing comparatively few spores (light) and a large quantity of wood (gray)

externally and internally, with hard paraffine or beeswax. A fume-cupboard with heavily painted windows is safe and convenient for this work, particularly if it is built over a soapstone sink.

After the coal is softened and bleached (as is the case where chlorates and *aqua regia* are used), it is carefully washed in running water until quite free from the reagents. In the case of highly bituminous coals, particularly cannels and the like, the pieces may be returned to melted phenol for some days. With most coals, especially those of later geological ages, it is necessary to wrap the specimens with bands of cotton fabric, held in place by stout linen thread. This precaution prevents the coal from going to pieces in the phenol. After the last treatment with carbolic acid, the combustible is washed repeatedly with warm water and then transferred to strong alcohol and finally to absolute alcohol, to remove all the water. Two or three changes of absolute alcohol are necessary. After the water is entirely removed the specimens are exhausted of all air under an air pump of high vacuum. In order to secure slices of the softened coal, it must be held together by means of nitrocelluloses. The best and least explosive of these is Schering's Celloidin, which is for the moment practically unobtainable on account of the war. It may be replaced with some degree of success by Anthony's photographic cotton. This is a less pure nitrocellulose and gives results which are less satisfactory. The dehydrated and air-free coal is transferred into a 2 per cent. solution of nitrocellulose in absolute alcohol and ordinary ether (of good quality). Absolute methyl alcohol gives better results than ethyl alcohol and is sold by the Bausch & Lomb Optical Company under the commercial name of Synthol. The material is secured in a strong bottle by means of a good cork wired in and remains for a day in a bath kept at the temperature of 70° Centigrade. It is allowed to cool and then transferred to a 4 per cent. solution of nitrocellulose in the medium indicated above. A second twenty-four hours in the heat brings it to a 6 per cent. solution. After the latter treatment it is enclosed in an air-tight chamber made from large diameter steam pipe. The corks are removed from the bottles preliminarily and by means of a valve in the cap of the chamber

and an automobile pump, pressure is raised to two hundred or more pounds. The coal remains under these conditions over night and has then become thoroughly infiltrated with the solution of nitrocellulose. The next step is to transfer it to a thick solution of nitrocellulose. In this it is placed again in the warm bath and after a time still further thickening is brought about by the addition of dry fragments of nitrocellulose. After several days of repeated thickening the specimens are now ready for the final process. This consists in transferring them from the thick nitrocellulose to chloroform. Chloroform has the valuable property of at once hardening the nitrocellulose and further softening the coal. After a stay of some hours in chloroform, which must not be used sparingly, the pieces of coal are transferred to a mixture of equal parts of alcohol and glycerine, where they may remain indefinitely, until needed for sectioning.

The fragments of coal treated in the manner described above are clamped in a heavy sliding microtome (the Jung-Thoma modified to the author's design answers very well for this purpose). A very sharp and heavy knife is employed for sectioning and its edge must be kept moistened with ordinary strong alcohol. The sections are turned back on the knife, as they are sliced, by means of a large camel's hair brush, wet with alcohol. Successful sections must usually be five micromillimeters or thinner. If the processes have been successfully carried out, abundant and consecutive slices can easily be secured, showing every feature of organization of the coal.

After the sections are cut they are dehydrated by means of absolute alcohol, to which a quantity of chloroform has been added to obviate the softening of the nitrocellulose in the coal. From the absolute alcohol and chloroform they are transferred to benzole or some other clearing medium and are then mounted in hard Canada balsam, dissolved in benzole or whatever clearing agent has been used on the sections. Where too high a degree of clearing is undesirable, as for example in the case of oil shales, chloroform may with advantage replace benzole or xylol. After the covers are put on, the preparations are allowed to dry for a day in a horizontal position and they are gradually warmed up with lead weights on the covers to promote flattening. When the balsam has become so thickened by the heat as to set in the cold, the slides are cleaned up. Where it is necessary to make photomicrograms of them, they are still further flattened by means of a clip clothes' pin acting on a disk of cork (over the cover) in the heat of a warm bath. For photographic reproduction, the best lenses (Zeiss apochromatics) are desirable and these should be used with a yellow screen and chromatic plates. Screens of other colors, although theoretically more desirable than yellow, have not been found practically to give as good results, probably on account of the difference between the visual and chemical focus even in the best microscopic lenses. The largest possible amount of light should be used, an end to be attained both by having a powerful electric arc as a source of illumination and the diaphragm of the sub-stage condensor opened to the widest possible degree, consistent with sharp focussing of the object. Naturally only the very best lenses will give good results under these conditions. The details of photomicrography are so familiar to all scientific workers in the field here described, that further details will only add unduly to the length of this article.

In conclusion are added, at the editor's request, some statements in regard to the bearing of the results obtained by the technical manipulations described upon the problem of the mode of formation of coal. It is to be noted that the mass of expert opinion at the present time regards coal as of the nature of modified peat and as having originated in most cases on wet land as the result of the rooting, flourishing and falling of successive generations of plants on the prostrate remains of their ancestors. This condition is realized in the cold, temperate regions of our earth. In the tropics,

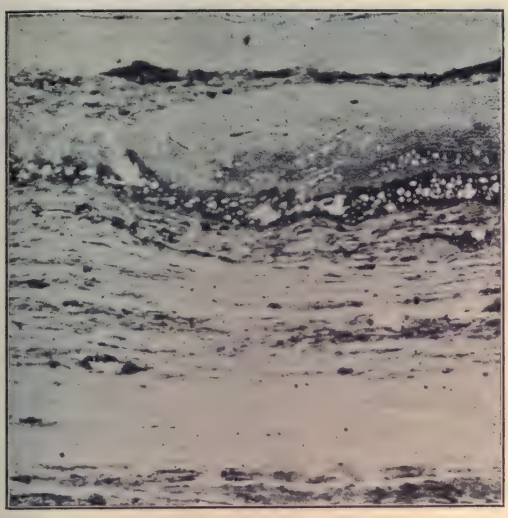


FIG. 5. Bituminous Coal from Illinois, showing gray woody bands and darker ones like cannel. Through the center runs a mass of charred wood ("Mother of Coal")

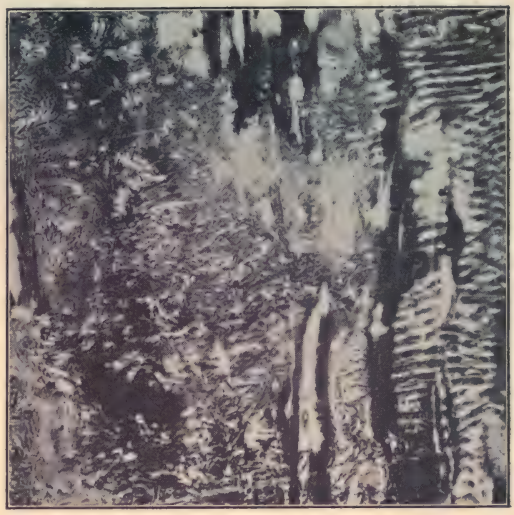


FIG. 6. Bituminous Coal, Hocking Valley, Ohio, showing longitudinal section of almost perfectly preserved charred wood ("Mother of Coal")

however, in spite of a luxuriance of vegetation, with which that of the greatest coal age (Carboniferous) has been frequently compared, there are no accumulations of vegetable matter on the soil. In warm climates the hoarding of plant remains occurs only in the bottoms of lakes and tranquil estuaries, since the high temperature makes the destruction of dead vegetable matter on land particularly rapid. Even in this country, which, as a whole, is neither particularly hot nor especially cold, we have the authority of the United States' Bureau of Mines (Peat Investigations) for the statement that by far the greater accumulations of vegetable matter occur under open water, which by its relatively constant level, safeguards the hoardings in its depths from the ravages of destroying fungi, since these are unable to flourish subaqueously.

The investigation of coals from all parts of the world and from every geological age, by the methods described in the earlier paragraphs, has made it clear that, in general, coal is of the nature of impure cannel. It is universally conceded that cannel coals, oil shales and similar combustibles, which constitute a small proportion of coals mined, were laid down in open water. We can best picture their mode of deposition by reference to a lake of today. Generally in the month of June the forest trees shed their fertilizing dust (pollen) in the air, to be borne by the winds to the waiting seeds. Most of the blossom dust is spilled, however, on the bosoms of lakes, lying in sheltered hollows, where the air currents losing their driving force drop their load of pollen, which falls on the waters as so-called "sulphur showers." After floating for awhile in circling windrows, the pollen sinks with other coarser vegetable matter into the depths of the lake or estuary. Where the pollen or spores were relatively abundant in the depths of the coal lakes of the past the result was a deposit which later became a cannel or oil shale. In more troubled and shallower waters a greater amount of the vegetative parts of plants accumulated with the spores and pollen, to constitute the raw material of a "fat" bituminous coal. Where the vegetative parts predominated a "lean" type of coal is the final result. Often in addition to spores

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Five numbers of SCIENCE CONSPECTUS are published during the year.

we find in coal wood with structure preserved, most inappropriately designated "Mother of Coal." This constituent, which is the record of ancient forest fires, frequently retains its organization so perfectly that it is possible to diagnose the type of tree from which it was derived. If the wood was only partially charred by the action of heat, its persistence as such in coal is correspondingly incomplete. Sections of coal ordinarily reveal two sorts of material showing recognizable structure: namely, "Mother of Coal" (relatively rare) and spores or pollen of the higher or vascular plants (more or less abundant). In addition to these structurally preserved constituents, combustible minerals are largely formed of a brown matrix resulting from the modification in the course of ages of the uncharred woody and other gross vegetable remains. With the fundamental brown of highly modified wood, the spores contrast by their golden yellow hue and "Mother of Coal" by its intense black (shading into brown in those portions incompletely charred). The mass of the coal has been subjected to enormous compression during the ages elapsed since its deposition in the bottom of the waters. As a consequence even its structural constituents are greatly flattened in the plane of the horizontal bedding or lamination.

The study of ultimate organization now rendered possible by improved technique appears to finally set at rest the controversy which has lasted for nearly a century and a half, in regard to the origin of combustible minerals. The generally accepted view of the way in which coal has been formed is that it is essentially, dynamically and chemically transformed peat. This conception which took its origin with von Beroldingen in the eighteenth century, has had its main defenders in Germany and as a result of the Teutonic scientific hegemony in modern times has been widely adopted in all parts of the world. In contrast to this hypothesis is the more logical view, cherished mainly in France, that coal is the consequence of organic sedimentation in open water. This opinion has been ably defended by Renault, Grand'Eury and many others, and there appears now no doubt that it is the correct one, since all the data derived from the microscopic study of coal, which must apparently ever be most cogent, are entirely in its favor. We must accordingly regard the hoardings of past plant life, preserved for us in the form of the various coals and their products, petroleum and natural gas, as having accumulated not in peat bogs but at the bottom of tranquil lakes, not *in situ*, but as the result of water transports.

BOTANICAL DEPARTMENT, HARVARD UNIVERSITY.
February, 1916.

CRYSTAL-MODELLING

A CURIOUS SYSTEM FOR CRYSTAL BUILDING BY WHICH NOT ONLY EXISTING FORMS, BUT ALSO NEW ONES MAY BE PRODUCED

BY EFFIE FRAATS CONNOR

I HEREWITH submit for scientific inspection a scale, or nest of solids, composed of five fundamental crystal forms, built of one-inch clay cubes.

This scale has taken its place in my mind with the music and color scales, proceeding, as these do, from the simple to the complex and from unity to diversity.

The science of crystal-building owes its existence to that ancient and mysterious structure, the Great Egyptian Pyramid; for it was while examining an article on the Pyramid in the *Science Conspectus* for February, 1913, that I conceived the idea of building its ideal form out of cubes. Having accordingly procured a quantity of modelling clay, I set to work.

After some weeks of the blindest experiment, I succeeded in constructing a perfect pyramid out of one-inch clay cubes, many of the n divided to conform to its surface.

Perceiving that I had built one-half of one of the five regular solids, I completed it, and fell to speculating upon the possibility of building the four remaining solids in like manner.

This effort occupied all my spare time for about two years; indeed, so difficult was the tracing of the form of the cube in the individual solids, and the consequent relations of the forms to one another, that I frequently forgot the combinations already secured and had to begin all over again. The result, however, justified the time expended; for before me appeared, finally, a great cube, with eight one-inch cubes, or units of construction, on each edge—five hundred and twelve cubes in all. By removing a certain number of these cubes, I found underneath the six surfaces of the 512-unit cube, the twenty triangular faces of the icosahedron,—that is, of the crystal form that most nearly coincides with it; for the fact that six opposite edges of this form are a trifle longer than the remaining edges, classifies it as a crystal and not as a regular solid.

The removal of a few more cubes from the icosahedron—which stands upon an edge—brings to light the twelve-faced pentagonal dodecahedron, or rather, the crystal form that very nearly coincides with it. This solid also stands upon an edge, but its edges cross the edges of the icosahedron at right angles, and each of its twenty corners lies directly in the center of one of the twenty faces of the icosahedron.

Within the dodecahedron is to be found the double pyramid, or octahedron. This has its twelve edges lying across the dodecahedron's twelve faces, and its corners lying in the middle of six of the dodecahedron's edges.

In this and the remaining cases, the crystal forms and regular solids coincide.

Within the double pyramid is enclosed an eight-unit cube, or hexahedron, with its eight corners marking the exact center of each of the eight faces of the double pyramid, and its twelve edges lying at right angles across the twelve edges of the double pyramid.

The eight-unit cube incloses the tetrahedron, its six edges lying diagonally across the six faces of the cube.

Reversing the operation, the six edges of the triangular "tetrahedron" expand into the six square faces of the cube; the eight corners of the cube expand into the eight triangular faces of the octahedron, the twelve edges of the octahedron expand into the twelve five-sided faces of the dodecahedron, and the twenty corners of the dodecahedron expand into the twenty triangular faces of the icosahedron; so that the final solid, which may

be inclosed in a 512-unit cube, is a great nest of solids.

It is not to be inferred that I suppose these five fundamental crystal forms to have been built by Nature out of cubes; they are built out of their solutions by the addition to their surfaces of minute particles. But that their ideal forms are constructed with reference to the cube, I do believe; and at any point of their growth the cubic relations are constant—the size of the unit-cube varying, however, with every step of their growth.

"The universe was built in order, and to us have been entrusted the will and the skill to discern that order."

This bit of wisdom has been handed down from generation to generation among scientists, but to most of us the universe continues to present a chaotic aspect. The ear, from the beginning, is greeted with a medley of sounds, until someone, by the simple expedient of measuring vibrations, produces a musical scale with its harmonies, and so enables us to trace variety back to unity.

Unrelated colors, too, surround and confuse us, until the prism separates a beam of light into its constituent colors and reveals among them a rigid order, also dependent upon vibrations, with harmonies as exquisite as those of music.

The vibratory sources of unity, order and harmony in the realms of sound and light, however, must be seen with the eye of the imagination; and with many of us that eye is not very keen. But in the preceding series of crystal forms, unified and brought into an orderly relation by the cube as unit of measurement, it is otherwise; for here is possible a protracted contemplation of the concrete representation of relations,—which contemplation is necessary in order to modify the *brain* sufficiently to enable the *mind* to grasp those relations. And when once the mind has been furnished with a model of the method of adjustment in the material universe, chaos is at an end; all departments yield to that magic key, and unity, order and harmony spring into being in whatever direction one turns.

This was the idea of Froebel, the founder of the kindergarten, who received his inspiration and his basic law while working among crystals. He called his law the law of the "Connection of Opposites," or Unity, and declared that without a knowledge of it his educational system was valueless. It is said by his biographers that he spent much time in trying to reduce the bewildering variety of crystal forms to one fundamental form—"presumably the cube."

Having become interested in crystal forms, and finding the text-books rather complex in arrangement and difficult to follow, I devised for my own use an entirely new system of classification. By using the series I have discovered as a basis, I am able to produce, by variation and combination, nearly if not quite all the forms that exist, to say nothing of inventing a few new ones.

The tetrahedron may be called the germ of the cube, as its six edges lie diagonally across the faces of every cube that exists.

My first step toward variety was in the manipulation of the corners, edges and faces of the cube. Extending these changes to the other members of the series, I found myself surrounded by diversity indeed, with all the "twinning" and combinations still to come.

I concluded that there should be a crystal with six-sided faces, and found by experiment that in order to inclose space such faces must necessarily include squares. I made the crystal, and when I looked for it, I found it in the text-book.

I am not at present able to determine whether the minerals of which these crystals are the indices have been brought into a more orderly relation by the classification upon which I have stumbled. But I should think this might be a subject of very great interest.

I believe the most important part of my education to have been accomplished during my experiments with crystal forms. I have noted my increasing love for symmetry and beauty of form, and can safely say that I derive as much satisfaction from the contemplation of crystals

as from music, or flower-hues or sunset tints.

I have also been forced to conclude that to become interested in anything whatever involves a process of brain-modelling, which in turn is dependent upon a protracted contemplation of the thing in question. And I have come to believe that a truly developed mind is a mind that can perceive complex relationships. Furthermore, this I *know:* in order to grasp a subject of a certain degree of complexity, the mind itself must have reached the same degree of complexity of development as the subject. I have conducted many experiments along this line—some of them in rather high educational walks—so that I am sure.

If I were a trifle more interested in benefiting humanity, I would, with these things in mind, endeavor to introduce crystal-modelling into our school system. The children of the kindergarten are already modelling cubes. It would be well to continue this good work in the primary schools, as no small difficulty is experienced in the division of clay into equal portions, the modelling of these portions into eight-unit cubes, the dividing of the eight-unit cubes into unit-cubes, and the perfecting of the same. This difficulty is owing to lack of perception and judgment, and of coördination between hand and eye—all of which are unquestionably stimulated and exercised by the clay work.

The grammar-school could go on with the modelling of the tetrahedron, and the high-school might be able to grasp the complex relations of the hexahedron and octahedron; but the remaining two forms would probably require the skill and judgment of the college mind.

To puzzle-lovers, and those to whom solitaire, and the like, have become irksome, the modelling of cubes offers a new and attractive occupation; an occupation that while it diverts the mind, not only disciplines it by the formation of new brain centers but also encourages industry and perseverance, and leads to method, order and system in dealing with the ordinary affairs of life.

Most of us have the minds of children because we have not been given an opportunity to develop and strengthen our capacity properly to relate things. When we hear one side of a story, we do not demand to hear the other side before coming to a judgment; we do not look forward to the effect of the cause we set in motion—nor do we trace the effect back to the cause, and so, in future, avoid or cultivate that cause. We do not classify or organize our mental contents, and so we soon lose our memory or experience difficulty in producing from our mental chaos what we would like to use.

Clay may be procured from any good kindergarten supply store in the form of flour. It requires to be moistened and worked into the right consistency with the hands. Experience only can instruct in this operation, but one should strive not to add too much water. After being used, it should be placed in a thick, damp cloth in a close vessel, so that it will not dry out. When it is in just the right condition the cubes will cohere in whatever position placed, and I know of no other substance that will do this.

When ready, the clay should be divided into equal portions that will make a cube two inches on each edge—that is, an eight-unit cube. After a number of these cubes have been made, they should be divided into one-inch cubes, and these cubes perfected.

Molds are not used, nor should the operation be performed by pressing the clay into shape with the fingers—except in the beginning in order to get the general form of the cube. It should, instead, be lifted and tapped lightly, with regularity and precision, upon a smooth board or any convenient surface, each of the six faces in turn, until a perfect cube emerges.

The following figures give exact directions which, if carefully followed, will produce the five fundamental crystal forms, graduated in size and related into a scale or nest of solids.

(*See cuts on following pages*)

FIG. 1. The one-inch cube, or unit of construction

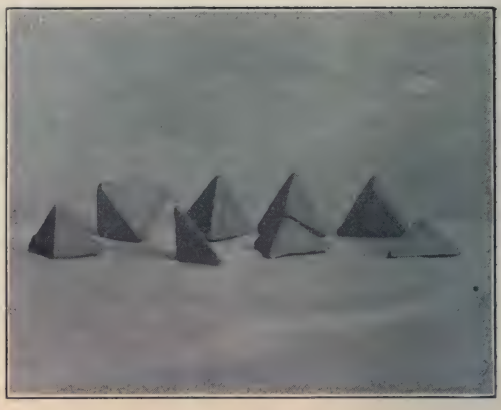


FIG. 2. Elements of the tetrahedron: four unit-cubes, each having had three corners removed; and three of these removed corners

FIG. 3. First step in the construction of the tetrahedron: the placing into position of four cube-corners

FIG. 4. The completion of the tetrahedron by the addition of the four remaining elements

FIG. 5. The twelve cube-corners, and four unit-cubes each minus one corner, which are required to build the eight-unit cube upon the tetrahedron

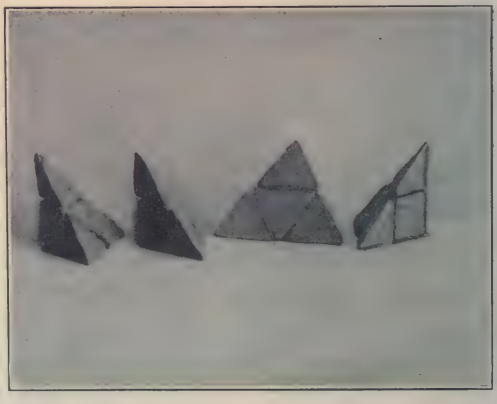


FIG. 6. The construction of four complex cube corners out of the elements of Fig. 5

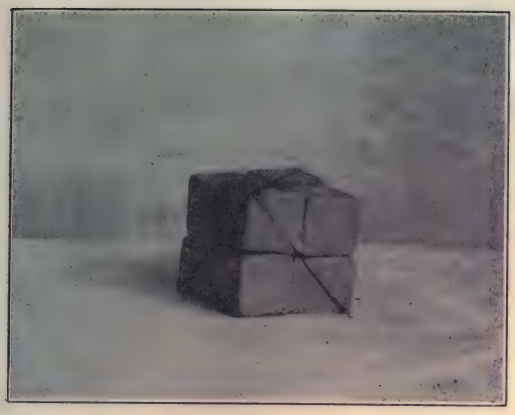


FIG. 7. The addition of these four complex corners to the tetrahedron, to form the eight-unit cube

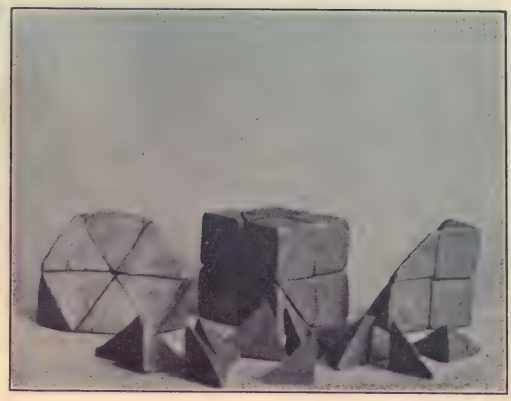


FIG. 8. The twelve cube-corners, and two eight-unit cubes each divided diagonally into halves, which are required to build the upper half of the double pyramid upon the upper half of the eight-unit cube

FIG. 9. First step in building the pyramid: place four eight-unit diagonal half-cubes into position

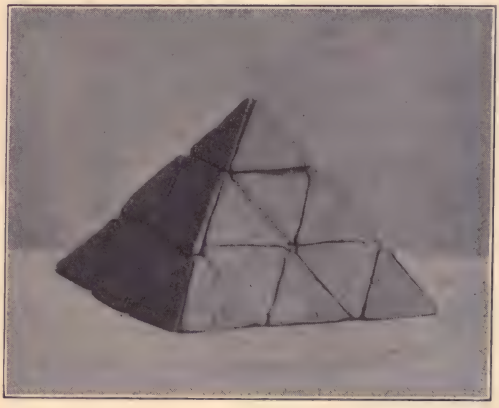


FIG. 10. Add the twelve cube-corners to complete the pyramid

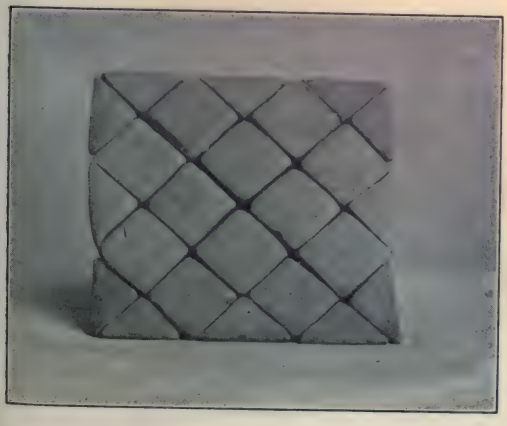


FIG. 11. View of the bottom of the pyramid (or center of the double pyramid) showing the upper half of the eight-unit cube in the center.

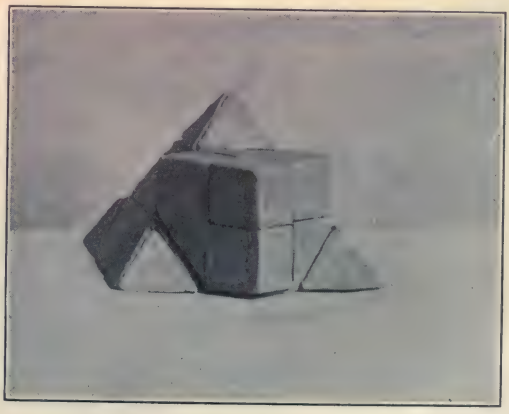


FIG. 12. First step in building the pentagonal dodecahedron upon the octahedron: place a diagonal half-cube upon each side of the pyramid

FIG. 13. Division of *two* unit-cubes to secure the additional elements required

FIG. 14. Further division of the resulting sections

FIG. 15.* Place these three sections into position upon the diagonal half-cubes which are against the sides of the pyramid; this produces one-eighth of the pentagonal dodecahedron, or rather, of the crystal form which approximates it. The remaining seven-eighths may be constructed in like manner. It will be noticed, however, that one-half of the divisions of two diagonal half-cubes, must be "left-handed": otherwise the perplexed modeler will find that the two halves of the form will not *go together!* When properly adjusted, the surface of each eighth will contain the halves of three of the five-sided faces of the dodecahedron. When the solid is completed, these half-faces unite to form the twelve complete five-sided faces of the dodecahedron

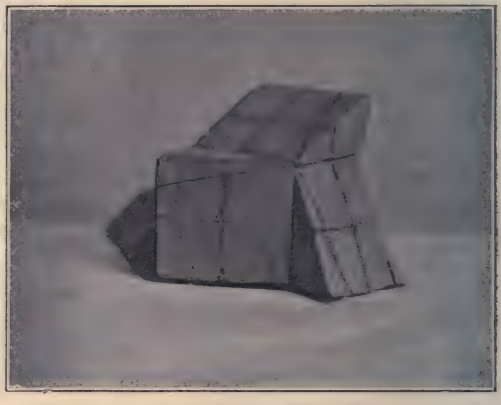


FIG. 16.* First step in building the icosahedron upon the dodecahedron: replace the sections that were cut from the diagonal halves of *two* unit-cubes

FIG. 17.* Second step in building the icosahedron: replace the diagonal halves of the three sets of two unit-cubes

*Small pyramidal projection at left is erroneous

FIG. 18. Third step in building the icosahedron: remove and place into position the three inner unit-cube corners

FIG. 19. New division of the diagonal halves of two unit-cubes, to secure the new elements required in building the icosahedron

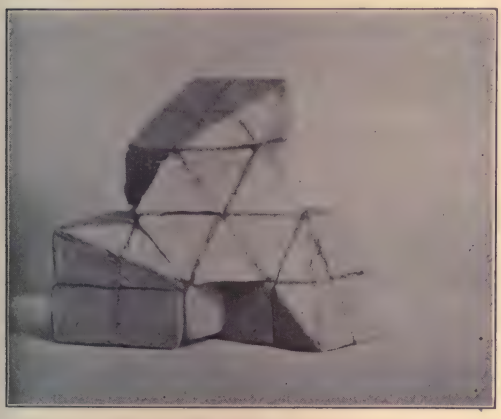


FIG. 20. Fourth step in building the icosahedron: place in position three of these new elements

FIG. 21. Fifth step in building the icosahedron: place in position three additional half-sections, which produces one-eighth of the icosahedron—or of its crystalline near-equivalent. It will be noticed that each eighth contains one of the twenty triangular faces of the icosahedron, and three half-triangles. When the remaining seven-eighths are added, these half-triangles unite to form the required whole triangles

Here again some of the sections of the diagonal divisions of two unit-cubes require a left-handed cut

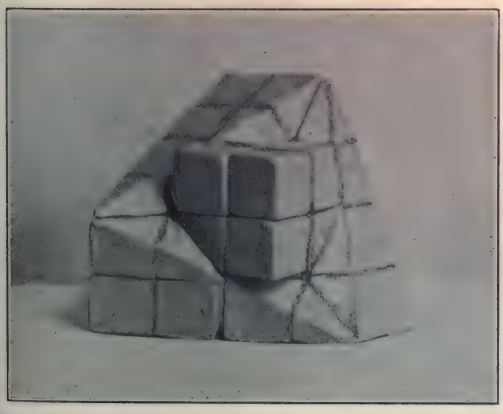


FIG. 22. Restoration to the eighth-icosahedron of the diagonal half of an eighth-unit cube

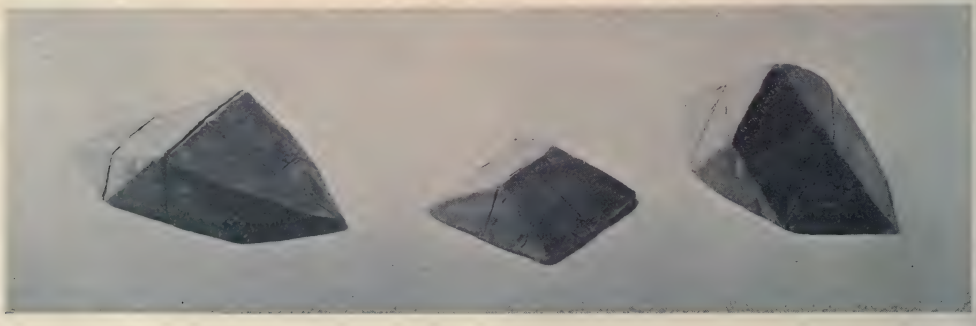
FIG. 23. Restoration of the removed section from three sets of *two* diagonal half-cubes

FIG. 24. Restoration of the three remaining diagonal sections of two half-cubes

FIG. 25. Rebuilding of the double sets of two unit cubes that were diagonally divided

FIG. 26. Addition of the three final sets of the diagonal halves of *two* unit-cubes

It is now plainly to be seen how to add unit-cubes in order to produce one-eighth of the great final cube having eight unit-cubes on each edge; which contains the whole nest of solids



c b a

FIG. 27. Six "a" forms, applied to each of the faces of an eight-unit cube, will produce the octahedron
Six "b" forms, applied to each of the faces of an eight-unit cube, will produce the pentagonal dodecahedron
Six "c" forms, applied to each of the faces of an eight-unit cube, will produce the icosahedron
These applications must be conducted by Froebel's "Law of Opposites"

SCIENCE CONSPECTUS

VOL. VI 1916 No. 4

CHEMISTRY AND PREPAREDNESS*

LOOKING FORWARD TO TOMORROW'S NECESSITIES FOR INSURING COMFORT, PROTECTION AND EVEN LIFE ITSELF, THROUGH THE EYES OF CHEMISTRY

BY HENRY P. TALBOT

WHEREVER chemists have congregated for general discussions during the last five years it has been commonly remarked that "chemistry is at last coming into its own in this country." Since chemistry concerns itself with all that is embodied in the concept of matter, that is, everything which is recognizable by any of our senses, it would be more accurate to say that "the chemist is coming into his own." If the comforting phrase is further analysed it seems to mean that, as a people, and particularly in our industrial relations, we are coming to recognize what the chemist can and ought to do for us.

The enormous natural resources of our country, as well as our national traits, have led to an industrial development in which efficiency in office and sales departments, resulting in "big business," has contributed far more to financial success than manufacturing efficiency. We have wasted our substance, and, what is equally significant, our sources of energy, to a degree which, viewed in retrospect, is nothing less than appalling. But at last there has been an awakening! Competition has grown keener. The trivial loss is no longer insignificant, and by-products have saved the day for many a manufacturer. Increasing refinement of product is constantly demanded. Our table salt must be more than 99 per cent, pure; the brown sugar of our forefathers is no longer acceptable, and the refiner of sugars is now forced in his own interests to recover the last crystallizable product from molasses; steel is no longer a material ordered from a few general types, but under rigid specifications which embody the results of scientific researches and correspond with exactness to the demands which the steel must fulfil. There are few commodities or materials in use in the arts of which it can be said that a quality which met the demands of two decades ago is now regarded as sufficient, and in the great majority of instances this increased exaction has been accompanied by a lessening in the selling price.

We, as a people, are also properly awakening to an appreciation of what science, notably chemical science, can do in the public service. Although still too tolerant in many respects, we have enforced some degree of compliance with restrictions which will prevent or lessen the indiscriminate discharge of noxious manufacturing wastes into open watercourses, or the discharge of destructive or offensive gases into the atmosphere. It is not long ago that the Blackstone River in the vicinity of Worcester annually became a fairly concentrated acid solution of iron sulphate during each summer period of low water. Many

* Substance of a paper read before The Tuesday Club of Newton, March, 1916.

other streams were rendered offensive by the discharge of wool-scourings in great quantities. But now many of the woolen mills are required, and all should be required, to work over this material within the mill, until the discharged waste is comparatively harmless, if not æsthetic in appearance. These, and thousands of similar problems, must find their solution in terms of chemistry, and where possible the waste product must be made a by-product and a source of profit, as is in some measure the case in the conversion of the objectionable wool-grease into toilet lanoline. If this is not practicable, then the expense of handling must be reduced to a minimum.

Greater, probably, than either or both of these factors in directing attention to chemistry and its possibilities of service has been the agitation in the interests of the conservation of our resources, a matter about which more will be said later in this paper.

The chemist, then, is "coming into his own" through the recognition by the captains of industry of the fact that, under prospective conditions, the financial success of a manufacturing process will depend more upon the development of better methods of control, the elimination of waste, the working up of by-products, and the intelligent purchase of raw materials than upon skilled salesmanship and enormous output, however important these may also be. These improvements are, to a very large extent, the proper affair of the chemist and chemical engineer, and members of this profession are now being associated with all sorts of industries, even those not apparently chemical in character, and are given the standing of resident physicians, instead of being called in, as has too often been the case in the past, to administer the last sacraments to a process already moribund, or even to fill the office of undertaker.

The relation and services of the chemist to the enactment and administration of our state and federal "Pure Food Laws," and various other measures which tend to conserve health, to promote the improvement of our road-systems, and to gradually assure a larger degree of economy, through larger intelligence, in all departments of administration of municipalities and states, attests the greater part which he now plays in public affairs.

Moreover, the chemist and his researches have achieved much for us that contributes to our comfort and happiness in a tangible way. Within the last few years synthetic dyes have been developed which exceed in brilliancy and durability the best of the natural dyes; artificial fibers which surpass in lustre the natural fibers; scents many times more powerful than natural perfumes; and synthetic drugs, the building up of which has effected profound changes in therapeutics, and alleviated much disease and suffering, besides putting new tools in the hands of the surgeon to diminish the pain and danger of his labors of mercy and healing. Artificial substitutes for bone, ivory, horn, leather, resins, rubber, and celluloid are at hand, and this is but the prelude to greater achievements.

Great as has been the productiveness of chemistry during our long period of peace, the science has received a remarkable impetus and has attained unlooked-for prominence as a result of the great war. Indeed, it is frequently asserted that the present struggle is essentially a war waged between the chemists and the mechanical engineers of the different warring nations, with chemistry in the foreground. It has even been made a reproach to the chemist, by some pacifists, that some of his most beautiful conquests and proudest discoveries have been converted into agents of relentless destruction and terrible human slaughter. But to place the blame upon him because nitrocellulose, which was first used to heal wounds (collodion), and to advance the art of photography, is stolen away from these pacific purposes to make smokeless powder; or because carbolic acid, which revolutionized surgery, has been made the basis of the powerful explosive picric acid, is, as a writer (Baekeland) has said, no less unreasonable than to condemn written

speech or language or the art of printing, because they have been used to disseminate the vilest lies and damnable errors.

Within bounds, the assertion that the present war is one between chemists is true (as, indeed, it is true of all other wars since firearms were invented), and the statement by a British author (Martin) that "British chemists believe that if their government had listened to them years ago the Germans would have been beaten in the early stages of the great war, and that thousands of lives would have been saved," and that "in the autumn of 1914 Germany was saved from a crushing defeat because she possessed the sense to encourage her chemists" can doubtless be substantiated.

In the discussions of preparedness in the public prints stress is naturally laid upon the training of men, and upon the manufacture of arms and ammunition. These are, of course, vital; but it is no less essential that in the event of war our supply of foodstuffs should be adequate, and that the industries which supply our daily needs should not be seriously impeded.

Our supply of animal foods is dependent upon our agricultural prosperity, and our food supply is therefore measured by the ability of the farmer to maintain the productivity of his soil. In a country which still includes such large areas of untilled land, the problem is naturally less acute than in the countries of the old world. But the problem is still present, for it takes time to open up new land for cultivation, and in some of the sections of the United States, like our own New England, the taking of crops from the soil has proceeded for so many decades that the farmer is already dependent upon an artificial replenishing of the ingredients demanded for abundant plant growth. Let us look into this problem of sustenance somewhat in detail.

Land plants require for their growth, beside the carbon and moisture taken from the air and soil, nitrogen, phosphorus and potassium in water-soluble form. The soils in which the plants grow are the product of the disintegration of rocks which, in turn, results from the action of the constituents of the atmosphere, particularly carbon dioxide and water. The soils contain the ingredients named above in varying amounts, but, if successive crops are taken from the same land, the local supply is gradually exhausted. Intensive agriculture then becomes necessary, and we resort to fertilizers made up of the soluble compounds of nitrogen, phosphorus and potassium, in proportions which, when real intelligence is exercised, are adapted to the particular locality and crop. Of these ingredients we as a nation are especially fortunate with respect to phosphorus. The phosphate beds in the United States are of great extent and there is no "phosphate question" of importance to consider, since the demands of agriculture are not likely to be exceeded, even under conditions of war, and there is a further large potential source of phosphates in some of the slags produced in the manufacture of irons and steels.

The Potassium Situation

The situation with respect to potassium and nitrogen is less fortunate, and the "potash question," as it is commonly called, is one of vital importance.

Under normal conditions the potash market in the United States amounts to about $12,000,000 annually. While this is small as compared with other products, its importance is relatively great. Some of our crops, such as beets, tobacco, and garden vegetables, require considerable amounts of potash for abundant growth, and nearly all require some potassium compounds. Potash salts are also used in smaller amounts in the glass, soap and match industries. Recently it has become evident that potassium compounds are employed in the manufacture of certain explosives, although the exact nature of this demand is known only to the initiated.

Aside from the limited deposits of potassium nitrate in India and Persia, the whole world's supply of potash salts come from the famous Stassfurt deposits in Germany and the less-known but im-

portant Alsatian deposits. In 1909–1910 came the controversy between the American importers, the German Kali Syndicate (a selling agency under Imperial supervision) and certain independent producers, which finally led to diplomatic exchanges between the governments. This served to focus attention upon the desirability of developing our own resources, and our predicament at the present time sufficiently emphasizes this. It is difficult to estimate how much potash salts are in the hands of fertilizer manufacturers and brokers, but there can be very little as compared with the immediate need. Purchasers have gone as far as Borneo in the endeavor to obtain fresh supplies. Germany is not likely to release potash salts during the war, and even at its close it is probable that the price will be materially advanced, since these salts form one of her resources which can and will probably be made to shoulder a large part of the war burden. On this account the ultimate control of Alsace is of added interest to the world at large. There are deposits of uncertain value in Galicia, Spain and Peru.

After the controversies of 1910, our government and certain private interests began an active investigation into the possible sources of potassium compounds in the United States. These investigations show that, under certain conditions, the United States can produce within her own borders an amount of potassium salts much more than her needs, and that the limiting conditions are commercial rather than physical. In other words, under normal industrial conditions, these potash salts can be produced when the market price will warrant the necessary expenditure; for the extraction of these salts from the materials available in the United States is by no means as easy as from the European deposits, from which they can be obtained by simple solution and crystallization.

Dr. Cameron, an authority on the subject, states that there are four notable sources of potash salts which have been under investigation. The first of these is feldspar. Feldspar, or orthoclase, a silicate of aluminium and potassium, is a constituent of many rocks, notably the granites. We have already seen that the potash naturally occurring in the soils comes from the distintegration of such rocks. The real problem, then, is to bring about an artificial disintegration consuming minutes rather than years. This has been shown to be practicable in itself, but the other disintegration products from feldspar besides the potassium compounds are not readily separated from them, and, without hand-sorting of the crushed rocks to concentrate the feldspar, which at once increases the cost of production to almost prohibitive figures for the present, the chemical separation is only partially successful.

A second potential source of potash salts is the salt deposits in the desert basins. Only one, Searle's Lake, San Bernardino County, California, affords much definite hope. The brine in this lake carries from five to six per cent. of potash salts, but it is impossible to separate these from other material by simple crystallization and the cost of more complicated methods is enhanced by the difficulty of operation in the middle of a large desert. The best that is at present predicted from this source is that it may yield a small quantity of potassium salts, of uncertain quality, as a by-product in the manufacture of sodium bicarbonate, the cooking-soda of our households.

As a source of potassium sulphate, the salt most used in fertilizers, a deposit in Utah of a mineral known as alunite, having a general similarity in composition to the potash alum of commerce, is of considerable ultimate promise. After roasting this mineral, potassium sulphate can be leached from the residue by water. Inaccessibility to a market for the product is, under present conditions, a limiting factor, but it is stated that there is expectation that this material will be worked for potassium salts even after competition with those of European origin again comes into play.

Finally, much has been published regarding the interesting production of potassium chloride from the so-called

Giant Kelps of the Pacific Coast. These sea-algæ have the power of appropriating a considerable proportion of potassium from the sea-water, potassium chloride being always present in the ocean in small amounts. These kelp beds along the coast of the United States and Alaska aggregate more than 400 square miles. They lie within one marine league of the coast, and are therefore controlled by the states, not by the federal government. The plants have an average length of 100 feet, of which 30 to 70 feet streams along near the surface. A cutting of from 4 to 6 feet has no noticeable effect upon the harvestable area, and the cutting seems to produce a stooling effect, causing the plant to grow more thickly and heavily. It seems probable that several cuttings a year may be made without damage to the beds, and that these beds alone might be made to yield, under careful and judicious harvesting, some six or seven times the present normal demand of the United States, whenever the market price is such as to yield a sufficient financial return. The harvesting is relatively easy, although considerable losses were sustained before the great power of resistance of this heavy wet material was demonstrated. The greatest difficulty lies in drying this slimy mass, to cause the separation of the desired salts or as a preliminary to burning. The fuel expenditure in the drying process is very high. While the dried kelp is itself good fertilizing material, the kelp-ash will probably command more of a market, if for no other reason than the high cost of transportation during the long haul to Eastern markets. The kelp will probably be most valuable as a source of pure potassium chloride, which is, in turn, used to manufacture potassium chlorate, an ingredient of almost all of the matches of today, and, as recent events seem to show, an important war material.

It is evident, therefore, that potassium compounds must be carefully considered in plans for preparedness, from both the agricultural and munitions viewpoints. Because of the long-recognized agricultural importance of the potassium salts the federal government, through its Bureau of Chemistry and Bureau of Mines, has already devoted much time to a study of our national resources as just outlined. Dr. Cameron, in commenting on this, writes as follows:

"While it is undoubtedly true that governmental efforts can yet furnish assistance, there is a very serious doubt as to how far these efforts should be continued. The time seems to have arrived when the commercial interests should themselves squarely assume the tasks confronting them and the costs of what further experimenting is necessary. This they have been slow to do, but there is rapidly accumulating evidence that these interests are responding to the spur of necessity, and that sooner or later potash salts from American sources are to be put upon the market. An early cessation of the European war might delay but can no longer stop the development of our potash resources."

While the view here expressed by Dr. Cameron may meet industrial needs, it seems evident that the federal government cannot afford to neglect to foster such a development as will ensure our ability to meet emergency demands such as are now upon us. Investigations should also be made to determine how far substitutes may, in emergency, be employed. It has already been found that, to some extent, the land plants can be made to assimilate sodium in place of potassium, and glass-makers have, under the stress of necessity, discovered that glasses can be made from soda (which in turn is made from table salt), which possess properties which were supposed to be attainable only through the use of the more expensive potash. Cut-glass, formerly made exclusively from lead and potash, is said to be a case in point. These discoveries, in two widely differing fields, are indicative of the conditions in applied chemistry in general.

Resources of Nitrogen

The third ingredient of fertilizers, already named, is nitrogen, and the "nitrogen question," because of its

bearing upon both sustenance and defence, is, as a matter of preparedness, the most vital of all, not excepting the selection of a system for military training of men. Privation and helplessness, even humiliation, may well be the penalties attaching to indifference to this question today.

It is desirable to distinguish clearly between what is meant by free nitrogen and fixed nitrogen. We live in an ocean of atmosphere some six or seven miles deep, composed essentially of free oxygen and free nitrogen. This nitrogen gas exerts a pressure of about seven tons upon a single square yard of the earth's surface. Assuming an average figure for the content of nitrogen in living matter, it is within bounds to say that this amount of free nitrogen would correspond to 50 tons of living matter, provided only that the nitrogen can be harnessed for service.

Free nitrogen is an inert substance, and serves merely as a diluent of the oxygen of the air. When we describe its properties we at once begin to state the things which it will not do. But the very inertness of free nitrogen is probably explained by its intense activity toward itself. Free nitrogen is assumed to be made up of molecules of nitrogen, each containing two atoms of nitrogen united to each other, thus $N \equiv N$. In order that free nitrogen may become fixed nitrogen, that is, nitrogen in combination with other elements than itself, it is necessary for the molecule to be broken down into its separate atoms, since chemical changes take place between atoms of the elements, that is, $N \equiv N$ must become $2\ N \equiv$. This separation is hard to effect, and conversely once effected, it is hard to maintain. More specifically still, there is a tendency for a nitrogen atom which has been induced to enter into combination with other elements to release its hold on them and to recombine with another atom of nitrogen. Hence free nitrogen is stable and indifferent, while many nitrogen compounds are unstable. Some are violently so, and are, as we shall see, our explosives; others constitute vital components of our animal and vegetable food-supplies, and of our own bodily structures. The latter type disintegrates, for the most part, peacefully. It is, nevertheless, their tendency to thus disintegrate which gives them their food value. Free nitrogen taken into the lungs is exhaled unchanged; but nitrogen assimilated as food becomes for the time a part of the animal body, and passes out of the animal system in the excretions, in the form of new nitrogen compounds, formed within the body. These return to the soil, are acted upon by bacteria in the soil and converted into soluble nitrates, which then exercise manurial properties, and are taken up by vegetation. The vegetable foodstuff is again eaten, assimilated, and the nitrogen compound again excreted. This is known as the nitrogen cycle, within which our lives seem to be set.

Aside from this supply of free nitrogen which resists efforts to convert it into fixed nitrogen, what have we at hand for use in our fertilizers, to sustain or intensify agriculture? We are restricted to soluble nitrogen compounds, essentially to compounds of nitric acid (the nitrates), and to the compounds of nitrogen with hydrogen (ammonia), and its derivatives, chiefly ammonium sulphate. The naturally occurring nitrates of sodium and potassium are now so valuable for their yield of nitric acid or potassium that, although they have of necessity been used in the past, ammonium sulphate is probably the substance of main significance for the future, so far as our natural supplies are concerned.

The commercial source of ammonia is chiefly that of a by-product in the manufacture of coke and coal-gas. When soft coal is heated in a closed retort or oven, volatile ingredients distil from it, made up of what we call coal-gas for illuminating purposes, coal tars, and ammonia. The ammonia is collected in water, in which it is very soluble. The ammonia water thus formed is treated with sulphuric acid, and the ammonium sulphate crystallized from the solution. The annual production amounts to about 1,250,000 tons, but this is far less than the

present demand, which will constantly increase. It is true that there has been an appalling waste of ammonia in the production of coke in the so-called bee-hive ovens, from which all the volatile products escaped into the air, but it is plain that even if this is reclaimed it will far from suffice in the future for agricultural needs.

A minor additional source of ammonia has been found in the cremation of garbage, and in procedures for the recovery of ammonia from water gas.

How then can we tap the atmospheric reservoir for material to protect our food supplies?

The bacteriologist has shown us one way by which Nature accomplishes this object by demonstrating that certain bacteria which find a residence in the nodules at the roots of leguminous plants, such as clover, and alfalfa, are able to assimilate free nitrogen from the air, and convert it into some compound which the clover, etc., in turn can assimilate into their structures. These plants can, then, be employed as miniature fertilizer factories, *in situ*, for, if the plants are subsequently ploughed in, and undergo decay and oxidation at the hands of other bacteria, the resulting water-soluble nitrogen compounds are taken up by the next crop. This is, to be sure, a partial relief, but obviously slow and insufficient.

But the chemist has discovered at least two commercially practicable procedures which are more rapid and significant. The first of these is the manufacture of cyanamide, a name which means but little to most of us. It is also known as "lime-nitrogen" and "*Kalkstickstoff*." This procedure has been made possible, in turn, by the development of the electric furnace. In these furnaces very high temperatures are attained by passing very heavy electric currents through the mass of reacting material, which, because of its resistance to the passage of the current, becomes highly heated, without the use of external fuel. It is similar in principle to the overheating of electric wiring by too heavy currents.

Calcium carbide, made in such furnaces from lime and coal, is familiar to us as a source of acetylene gas, when treated with water. If free nitrogen is passed over this carbide under suitable conditions, it combines with it to form what is called calcium cyanamide. This, in the presence of water, gives ammonia as one of the reaction products. The cyanamide can be also used directly as a fertilizing agent.

Two features of this process require further attention. The nitrogen used must be nearly free from oxygen. Fortunately, methods are known by which such a separation of the two main constituents of the atmosphere can be brought about. Air can, today, be liquefied with ease, and the resulting liquid consists, of course, of a mixture of oxygen and nitrogen. This may be compared with the mixture of alcohol and water which we are accustomed to use in winter in the radiators of automobiles. It is well known that the alcohol "boils away" first from such a mixture, and the reason is that the alcohol is more volatile, that is, has a lower boiling-point than water. If we were to collect and examine the first portion of the vapor from such a mixture, it would be found to be nearly pure alcohol. Now nitrogen is more volatile than oxygen. Hence, if liquid air is allowed to evaporate, under regulated conditions, the nitrogen escapes first from that mixture, and such nitrogen corresponds to the alcohol above and is so nearly pure that it can be readily freed from remaining amounts of oxygen. This is, in mere outline, the way in which the free nitrogen is obtained from the atmosphere in quantity today, as a first step in the processes for its fixation. It is fundamental to the success of such processes as we are now considering.

The second point to be emphasized is that electrical energy is used as a source of heat, and, as is well known, water-power is usually the cheapest source of energy. This process has accordingly found its chief development in Norway and Sweden. It is stated that an English company is planning the application of 1,000,000 horsepower in Norway and

Iceland, in addition to the 200,000 now in use in various places, for the production of the cyanamide. It is significant that not a single factory exists in the United States, although we have much available water-power.

The second chemical procedure for the "fixation of nitrogen" is the direct union of nitrogen with hydrogen to form ammonia. This has been developed in Germany by Professor Haber and the chemists and engineers of the Badische Anilin and Soda-fabrik. The nitrogen is obtained in the way just described. The hydrogen is probably obtained by the electrolytic decomposition of water. The two gases do not readily combine, but under a great pressure of 3000 lbs. per sq. in. and at 500° C. they can be made to combine, in the presence of a catalyzer, that is, a substance which merely by its presence increases the rate of a chemical change, its effect being sometimes compared to the lubricant on the works of a clock. Uranium is the substance supposed to be used in this case.

That this process is a commercial success is beyond question, and it is in part due to it that Germany has not long ago exhausted her supply of ammunition, for, by another process, involving the use of a different catalyzing agent, ammonia and air can be converted into nitric acid, and without nitric acid not one of the explosives in actual use in peace or warfare could be manufactured.

The world supply of nitric acid has, until recently, been derived from natural nitrate beds, composed of sodium nitrate, located almost entirely in Chile and Peru. It is known as Chile saltpetre. There is some potassium nitrate in India. The nitrates can only be found in an almost rainless country, as they are very soluble in water.

Chile has an annual output of about two and a half million tons of nitrate. The United States takes from one-fifth to one-fourth of this output. It is estimated that about 50 per cent. of the nitrate imported into this country is used for explosives, 25 per cent. for the manufacture of nitric acid for other uses, and 25 per cent, as fertilizer. It is, of course, very valuable for the last-named purpose.

Sir William Crookes, in his presidential address before the British Association for the Advancement of Science in 1898, dwelt with great earnestness upon the serious necessity for the development of processes which should enable us to obtain nitric acid from other sources, since the visible supply of natural nitrates seemed likely to be exhausted by the middle of the present century. The seriousness of the extreme localization of these supplies finds forcible illustration in the present situation of Germany.

More than a century ago Cavendish pointed the way to what, in point of time, was the first commercial process for the production of nitric acid from the nitrogen in the atmosphere. He showed that nitrogen and oxygen, both of course close at hand, will combine to some extent when an electric spark is passed through a mixture of the two gases. An oxide of nitrogen results, from which, on contact with hot water, nitric acid is formed. The yield was very small, and unpromising. Under the stress of approaching need, this process was studied anew. It was found that by spreading out the electric discharge by means of electromagnets the gases could be exposed to an electric flame several feet broad, and by a suitable and regular removal of the products of the change, the yield could be greatly increased. Here, again, oxygen and nitrogen are readily available, but the generation of electrical energy at a figure which would permit of a possible competition with natural nitrates under normal industrial conditions would presumably require the use of water-power to drive the generators. The first commercial plant to operate under this procedure was built in 1902, at Niagara Falls, on the American side, by two American pioneers, Messrs. Lovejoy and Bradley, and to them belongs the credit of having furnished the first answer to Crookes' call of distress. In all probability they also laid the foundation for a development which has made it possible

for Germany to challenge the world at arms. Why is this plant not in operation today? Simply because the authorities failed to take the slightest interest in the matter, and private capital was suddenly withdrawn. Abroad, however, the situation was different. In Sweden and Norway, with cheaper water-power, and upon the foundation of the experimentation of Lovejoy and Bradley, backed by plenty of capital in the hands of well-advised bankers, and aided by the coöperation of established industries, the "fixation of nitrogen" in the form of nitric acid has been greatly developed. The best known process is that of Birkeland and Eyde, based upon the principles just briefly outlined.

Directly or indirectly the Birkeland and Eyde process, and its modifications, has played a conspicuous part in Germany in the production of the required quantities of nitric acid, and must receive serious attention in our own country, if we are to meet the future demands upon a peace or war footing.

Other procedures for the production of ammonia, in which, for example, the free nitrogen is made to combine with aluminium, and the resulting nitride is treated with water, the Surpeck process, are of potential importance, but must be passed by with this mere reference.

Nitrogen for Explosives

If we exempt potassium chlorate, there is no useful explosive which does not require nitric acid for its manufacture. As an index of the probable future needs, it is of interest to trace briefly the development of the modern explosives as used in the great war.

The useful explosives may be subdivided into the propellants, employed in ballistics, and high explosives, used in blasting operations, and in torpedoes, mines, bombs and shells. Only those substances can be successfully used as explosives which concentrate in a small space materials which will act upon each other with enormous rapidity, generating great volumes of gas, and liberating large quantities of heat, which, by expanding these gases, give rise to the propellant or rending force desired. Measured in our ordinary units of time all explosive action seems to be instantaneous, but accurate measurements show that there are real differences in the rate of decomposition, and it is exactly this which determines whether or not a given explosive can be used as a propellant. It is required of a perfect propellant that, "when fired in the breech of a gun, the combustion or decomposition shall commence comparatively slowly, gradually overcoming the inertia of the projectile without putting too great a strain on the gun itself, and then that the decomposition shall increase in rapidity, thus supplying gas more and more rapidly, accordingly increasing the momentum of the projectile, which should leave the muzzle of the gun with maximum velocity."

Within certain limits gunpowder is a satisfactory propellant, but smokeless powder is far more satisfactory.

Professor Lewes, an English authority, furnishes some interesting comparisons. At the time of Napoleon's activities, the *Victory* was the most heavily armed British ship afloat. Her broadside of 52 guns, if fired simultaneously, would throw about 60 per cent. of the weight of metal contained in one shot from a 15-inch gun of a superdreadnought. The 68-pounders of the Crimean war, using a charge of 16 pounds of black powder, are now replaced by the 15-inch guns, weighing 100 tons, from which a charge of 100 pounds of cordite (a smokeless powder) hurls a projectile weighing 1925 pounds with accuracy to a distance of 15 miles, or, with high angle firing, to a much greater distance.

About 1850, the rifling of the bore of the guns was introduced, with a gain of range and accuracy, but requiring the lengthening of the barrel. At the Siege of Alexandria in 1882, 80-ton guns, of 16-inch calibre were used, while in 1886, 110-ton guns, with $16\frac{1}{4}$ inch bore, requiring a charge of 960 pounds of powder, were employed.

It was found, however, that gunpowder was not a satisfactory propellant

under the new conditions, since the velocity of gas generation decreased as the surface of the grains diminished in area, as they were consumed. Various expedients were tried, but none successfully. Moreover, the products of decomposition of gunpowder are about 50 per cent. solids and remain as smoke, obscuring the vision of the gunner, and inviting attack from the enemy. A smokeless powder was evidently a necessity.

Schönbein, as far back as 1845, had prepared an explosive nitro-cotton, or nitro-cellulose, from cotton and nitric acid. It was natural to turn to this material. But it proved to be a high explosive rather than a propellant.

When cotton is treated with nitric acid, it is converted into nitro-cellulose, but it does not thereby lose its natural structure. Under the microscope the fibers of both cotton and guncotton are found to consist of very minute tubes, and if any of the gun-cotton begins to burn, the flames are forced by the high pressure into these tubes, and the whole mass decomposes so fast as to subject the guns to dangerous strains. It is as though one were to fan flames into a pile of straws; the inner and the outer surfaces would be exposed to the igniting effect of the flames.

Nitroglycerine is an even more rapid explosive; and dynamite, which is nitroglycerine absorbed in earthy material, while less dangerous to handle, is equally impossible as a propellant. It is of interest to recall in passing that Nobel, of peace-prize fame, was the inventor of dynamite.

In the course of time, it was found that if the nitro-cellulose is dissolved in acetone (an organic solvent derived from wood-distillation), and the acetone evaporated, the nitro-cellulose which is then recovered has lost its tubular structure, and then burns less violently. This was the basis of smokeless powder as late as 1888. It was far superior to gunpowder as a propellant, and yielded only gaseous products. Since then there have been innumerable patents issued for combinations of explosives under trade names. A typical case is that of cordite, much used by the Allies, which consists of nitroglycerine and nitro-cellulose, first dissolved together in acetone, with subsequent removal of the solvent. Under these conditions the nitroglycerine goes to pieces more slowly than when used alone. Some vaseline is said to be added, which gives added stability and lubricates the gun. The material is cast into sticks, rods or cords; hence the name.

The introduction of the smokeless powders caused an immediate change in gun construction, with a reduction of bore to 15 inches, and smaller firing chambers, since a charge of 400 pounds of cordite replaces the 600 pounds of prism powder, while a 50 per cent. increase of velocity at the muzzle is attained, using a heavier projectile.

It is clear that the permanence during storage of these smokeless powders is a matter of first importance, and many combinations otherwise satisfactory have failed in this respect. Many magazine explosions have been the result of spontaneous decomposition, accelerated by even slight amounts of decomposition products.

In contrast with the propellant, the successful high explosive must produce its maximum effect in the shortest possible time. These are used in the various forms of projectiles, mines and torpedoes. The two last-named may be included with shells and bombs for our present discussion.

Shells are of two general classes: shrapnel utilized against troops in the field and high explosive shells intended to pierce armor-plate, or reduce earth-works or wire entanglements. The shrapnel shell, as described by writers on the subject, is a hollow cylindrical steel projectile packed with bullets, at the base of which is a bursting charge that may be gunpowder or high explosive, while in the nose of the shell is arranged the time fuse connected by a tube to the bursting charge, and so regulated that the shell can be exploded in the air at any desired point, the bullets and fragments of the shell being driven forward and spreading

over a considerable area. The shrapnel used in the ordinary field gun is an 18-pound projectile, containing 375 bullets, and when burst at the right altitude is a most deadly weapon against troops, especially when in massed formation.

The high-explosive shell is made of forged steel with comparatively thin walls and a heavy bursting charge, but the large naval shells and those for the siege guns, which have to penetrate heavy armor, are made from ingots of chrome or chrome-nickel steel, forged, hardened, and the nose capped with soft steel, which prevents the shell from shattering on impact with the hardened steel armor. These shells also contain a heavy charge of high explosive, generally cast into the shell in a fused condition.

Grenades are of the character of miniature shrapnel, but are filled with all sorts of fragments. The surgeons report finding among other miscellany victrola needles within the internal economy of their patients. It is striking that, in the use of the grenade, there has been a return to the employment of the ancient catapult. The flight of the grenade through the air is steadied by a rod, if fired from a gun, or a rope tail if fired by hand.

The high-explosives employed in the various projectiles doubtless vary greatly. They include nitro-cellulose, and probably nitroglycerine in admixtures. But we also find another type of explosive largely used, which is obtained by the action of nitric acid upon some of the coal tar products. Two typical examples of such products are picric acid and trinitrotoluene, called T. N. T. The first of these is made from carbolic acid (phenol) by a nitrating process. It is a yellow powder. Phenol occurs in coal tar, but not in sufficient quantities to meet the present demand, and is made from benzene, another coal-tar product.

Picric acid itself can be melted and poured into the shells. It is *per se* a safe explosive, but it forms compounds with the metal containers which are very treacherous and very unstable. It also requires a powerful detonator, to ensure the high explosive effect, and this has led to some premature explosions of shells within the guns.

A somewhat less powerful explosive, but one which has not the disadvantages of picric acid, is the trinitrotoluene. The pressure produced by the former is 135,000 pounds per square inch, as compared with 119,000 for the latter. It does not attack the metal containers, and when mixed with other explosives produces such a shattering effect that the fragments of shell are larger and more destructive when in contact with earth works or wire. These shells on bursting emit an intense black smoke, which aids observers in determining the effectiveness of the gun-fire. The shells are known as "Jack Johnsons" or "Black Marias." The stunning and benumbing effect on the men in the trenches is also said to be greater.

One of the most powerful explosives known appears to be a tetra-nitro-anilin while a close relative, tetra-nitro-methyl-anilin, known as "tetryl" is used as a primer or detonator.

Both picric acid and T. N. T. will burn quietly in the open, if ignited.

How, then, are they, and other similar materials, brought to explosion? In some cases by actual ignition. For example, the heavy charges of smokeless powder in the guns are usually ignited by means of a small charge of gunpowder placed in the chamber with the propellant, and this, in turn, is ignited by a detonator, which, as a rule, is a substance which is caused to decompose by shock. The so-called fulminate of mercury such as is used in ordinary cartridges, and exploded by the blow from the hammer of the weapon, is a material of this sort. When struck it explodes, either from the vibration of the blow or from heat generated by the blow. The explosion of the fulminate starts certain vibrations in the air or ether, and these seem to be of such a character as to be taken up by the molecules of the explosives, with the result that these, in turn, become disrupted. It is, in principle, like what occurs if a bow is drawn across the string

of a violin in front of a piano, when the loud pedal is pressed down. The single string of the piano which corresponds to the tone of the violin in its length of vibration will respond. It is also similar in principle to wireless telegraphy, save that in both these latter cases no decomposition of material ensues, while in the case of the explosive the molecules are shattered by the vibrations from the explosion of the fulminate.

The explosives all give out heat when they decompose, and heat, in turn, always hastens any chemical change. Hence, any decomposition caused by the vibrations of the detonator is at once propagated through the mass.

In the incendiary bombs, which are recently so much in evidence, they have found phosphorus, inflammable liquids of various sorts, and a mixture known and used in the arts, and called thermite. It consists of a mixture of oxide of iron and powdered aluminium. When ignited by a primer just before the bomb bursts, it generates an intense heat, and molten iron is scattered in all directions. This iron is, indeed, far above its melting point, attaining temperatures as high as 3000° C. Its incendiary capabilities are sufficiently evident. It is stated that phosphorus has also been incorporated in shrapnel and grenades. It aggravates the wounds produced, since the tissues burned by the phosphorus are only very slowly restored. It is also true that the phosphorus, which takes fire on exposure to the air, leaves a cloud of white smoke by day and a flask of fire by night, which again aids in locating the fall of the shell. They have been called the "woolly bears."

Of the raw materials demanded for these explosives, outside of nitrogen, we are fortunate with respect to cotton, iron, fuels and metals, although there is an enormous demand for cotton. An adequate supply of glycerine calls for foresight. It is a by-product of the soap industry, and can be obtained from animal fats, and from some vegetable oils by other processes, but the ordinary sources of supply would probably have to be augmented to meet war requirements.

The poisonous gases employed in the present war appear to be chlorine, or mixtures of chlorine and some bromine. Both act violently upon the mucous lining of the throat and lungs, 2 per cent. by volume of chlorine often proving fatal. Bromine is, if anything, even more poisonous than chlorine. It is a liquid at ordinary temperatures, and is supposed to be used in shells, since the liquid is scattered as such, and on evaporating, does its cruel work. According to accounts, liquid chlorine, or more probably chlorine gas, has been forced through pipes in front of the trenches, and carried by the wind against the enemy. Only a heavy gas could be thus used. If chlorine is a fair weapon, we have a plentiful source of it in our salt deposits.

Liquid Fuel

Both aircraft and undersea boats, in their remarkable development, have presented new problems which must be duly considered in a preparedness program. From a chemical standpoint the most urgent of these are adequate supplies of liquid fuels, and the devising of metallurgical products which shall combine maximum strength with minimum weight. Much advance has been made in the production of alloys of aluminium and magnesium, the two available metals with the least specific gravity.

The liquid fuel problem is upon its face one of some seriousness. In this country gasoline may be said to be almost the only liquid fuel in use to drive the internal combustion engines. The use of these engines has increased with enormous rapidity, not only as motive power for vehicles and boats, but as stationary engines, and in the form of portable engines for farm use, concrete mixers, and the like. In the war area such motors are attached to almost every movable object from aircraft to ambulances, and even to field and siege guns. The heavy petroleum oils, from which the gasoline has been removed, are also used as fuels on some of our battleships, on some of the western railroads, and for boiler plants

in localities in which such oil is readily obtainable at low cost.

Gasoline is not a chemical entity. It is a name for a mixture of volatile substances obtained by distillation from the crude natural petroleums. The supply of natural gasoline must ultimately depend upon the supply of these crude oils. Before the advent of the gas motor, the oil refiners were at a loss to find a market for these volatile oils. The burning oils, kerosenes, were made to carry as much gasoline as the rigid legal requirements regarding fire-tests would permit. Today the situation is reversed, and the gasoline at present on the market carries as much kerosene as the traffic will bear, that is, as much as can be used and still retain sufficient volatility to enable the vapor to pass with air from the carburetor to the cylinders of the engine in adequate quantity. Both carburetors and engines have been modified to meet this necessary change in the character of the fuel supply. Is the demand for such fuel actually outstripping the supply even upon a peace footing? The rapid rise in the price of gasoline would seem to indicate this, but an analysis of the situation leaves the matter somewhat in doubt, at least so far as the immediate future is concerned. The question is dealt with in detail in a communication dated February 2, 1916, sent to the U. S. Senate at its request by the Secretary of the Interior. The total production of crude oil in the United States in 1900 was 63 million barrels, in 1915, 266 million; that of the world in 1900 was 149 million. In 1915 it had risen to 400 million. The consumption of gasoline in the United States in 1899 was about 7 million barrels, in 1915 it was 41½ million. The ratio of increase of production of crude oil is about 1:4⅓; the gasoline consumption 1:6. This result has been made possible by improved refinery methods, and by alterations in the character of the burning fluid known as gasoline, as just described.

In his response to the Senate inquiry as to the cause of the sudden rise in the retail price of gasoline, the Secretary names six contributing factors: (1) Increased consumption of gasoline, which was 25 per cent. greater in 1915 than in 1914; (2) Increased exports (about 1½ million barrels in 1915); (3) Depletion of stocks of gasoline held in January 1915. There is almost none so held today; (4) Decrease in the production of crude petroleums yielding the larger percentages of natural gasolines. In the "Cushing field" alone, the wells were, some months ago, yielding less petroleum than in April, 1915, by an amount equal to 50,000 barrels of gasoline a day; (5) Increase in price of crude petroleum, which has been advanced from $1.45 per barrel on Jan. 1, 1915, to $2.25 per barrel on Jan. 1, 1916. Gasoline has advanced from 12 cents to 21 cents (wholesale) in the same interval. If this advance in the price of the crude oil bears any relation to the ultimate natural supply, it must apparently be anticipatory to a large degree. The price of gasoline has advanced more than proportionately, but this may be partially accounted for by temporary inability of refiners to handle the necessary volume of crude material; (6) the last factor is what the Secretary calls "Financial influences" and under this caption he discusses the fluctuations of the stock quotations, and concludes that in the case of the larger and stronger companies the price which the consumer pays does not depend alone upon the cost of crude material.

Apparently, then, the current price of gasoline is not an accurate measure of the imminence of a dearth of liquid motor fuel.

Other figures of interest are also to be found in this letter. Experts have estimated that, taking into account the known possibilities, the various so-called "fields" of petroleum have been exhausted to amounts varying from 8 to 93 per cent. But they also estimate that these fields may yet be counted upon to yield something like seven billion six hundred million barrels of crude petroleum. There is no accurate factor by which to translate this into gasoline because of changing practices; perhaps it may represent two billion barrels.

These figures also take no account of the oil-shales known to exist. These are rocks more or less saturated with petroleum. The total possible yield from shales of the same character as are now worked in Scotland might furnish further billions of gallons of crude petroleum.

So much for the natural gasolines. But our resources are by no means exhausted with them, although the situation demands careful and intelligent study, if we are to be in a position to meet emergency demands.

In the first place, we have means by which we can produce what may be called artificial gasolines. We are already condensing to a liquid, the natural gases which are associated with the petroleum deposits and mixing this very volatile material with kerosene, the mixture constituting an artificial fuel.

It has, moreover, been found that there are several ways in which the less volatile components of petroleum can be decomposed into substances which are readily volatile, and at least two commercial processes are now in operation to effect this conversion of heavy liquids into what is, in effect, a gasoline. These volatile substances are, in turn, used directly, or are mixed with some kerosene to make a burning fluid of acceptable quality. In this way the proportion of available material for gas-motors is much increased. It will be some time before such operations can be conducted on a 50,000-barrel-a-day scale, and we may probably expect to see the price of such fuel continue to advance in the immediate future if the principle of supply and demand is the controlling factor.

But gasolines are not the only type of liquid fuel which it is possible to use in motors. In Europe, benzol, a coal-tar product, has long been used, and it is reported that Germany is using at the present time a mixture of equal volumes of alcohol and benzol, with much success. The production of benzol is essentially controlled by the market for coke. Alcohol can be produced in great quantities from potatoes, and also from sawdust and wood-waste. Both benzol and alcohol have the disadvantage that they are less volatile than gasoline, and require a "starter" of gasoline, but, with modifications of our present devices, particularly with respect to electric heaters, their use is practicable. In Germany they are said to be using gasoline to start the motor.

Obviously, the gas-engine has proved its claim to permanence, and the importance of this form of motive power in peace or war can hardly be overestimated. If we have plenty of time to prepare, the liquid fuel problem may not be serious. In an emergency, it behooves our government to be ready to meet an acute demand.

The lighter-than-air craft has not apparently appealed to the Allies. If we should determine to add zeppelins to our outfit, hydrogen is to be had in plenty, by the electrolytic decomposition of water, for initial inflation. To supply the constant loss through the envelope, an apparatus similar in principle to the acetylene generators formerly used on automobiles is now used, in which water can be dropped on a solid mixture such as silicon and caustic soda. Hydrogen gas is thus generated, and can be introduced into the envelope to compensate for losses. This apparatus is either carried on the dirigible or transported by automobile as needed.

Prognosis and Research

These are but a few of the material demands which would confront us if our preparedness is ever to be tested. But back of these and vastly more important than any one of them is the need for something like an adequate notion on the part of our government, and our industrial leaders who must actually supply our material needs of what research and scientific method stands for and can accomplish. However we may criticize Germany, we cannot avoid a tribute of respect to the thoroughness with which she not only anticipated the events and material conditions of the war, but has met the rapidly changing conditions with fresh and more efficient weapons and mu-

nitions. It is impossible to think of Germany as entering a war as we are said to have entered the Spanish war, with black powder, when all other nations, even Spain, were using smokeless powder. Nor can we think of Germany, or perhaps any other of the nations, with our resources and self-assumed responsibilities to our neighbors, continuing with but one single small plant (in North Carolina) equipped to fix the nitrogen from the atmosphere, without which it is hardly too much to say that we might be brought immediately to our knees in the event that the South American supply of nitrate was suddenly stopped by our enemies.

The well-worn expression "in times of peace prepare for war" can nowhere be better applied than in the encouragement of research. Our army and navy departments are not like our industrial concerns. The latter can afford to temporize and take chances on producing a profit from the use of antiquated machinery or methods. In the contest of war there is no quarter for weapon or craft that was the finest *yesterday*, and no time to wonder how the enemy manages to keep one lap ahead of us.

There is much evidence to show, in chemistry at least, that we can at least hold our own in the embodiment of chemical principles and laboratory processes in profit-producing large-scale plants, but we do need to cultivate a greater appreciation for the research spirit, which alone makes it possible to attack the new problems fundamentally: it represents the difference between office efficiency and manufacturing efficiency. We need far more of this spirit infused into the education of the selected body of youths in our colleges and we need to offer far more encouragement to research through added endowment. Meanwhile we must be thankful to Secretary Daniels for building possibly better than he knew when he proposed the Naval Consulting Board. Their proposal of five million dollars for research seems at first an excessive expenditure, but the single item of corrosion of boiler tubes involves a direct or indirect damage of $2,000,000 a year to the navy, and a single private concern manufacturing automobiles finds it economical to spend a half million dollars a year in research and experimentation.

Some of the ablest men of the country are giving their best thought to the work of this Naval Board, and it deserves the support of all of us who are in a position to appreciate its deeper significance, including its influence upon all research in both pure and applied science throughout the country.*

SUNLIGHT AND THE MAGNETIC NEEDLE

Considering how many centuries have elapsed since magnetic phenomena first became recognized on this planet, it is remarkable how little has yet been learned concerning the nature and laws of magnetism. All that we are able to affirm, with a reasonable degree of certainty, is that whatever electricity and magnetism may be, they must be so interrelated that one is the consequence of the curl of the other, which is one aspect of Maxwell's electromagnetic theory.

As an instance of our magnificent international ignorance of the nature of terrestrial magnetism, the simple historical fact may be cited that in 1582, the date of the international introduction of the Gregorian Calendar, with a sudden jump of ten days, the magnetic needle at London pointed 11 degrees easterly of the geographic meridian, whereas it now points nearly 16 degrees westerly of that meridian, and in 1820 nearly attained 25 degrees of westerly declination, a total of more than 36 degrees, while no satisfactory theory of the large change has yet been produced.—*Electrical World.*

*The federal government is now interesting itself actively in the nitrogen question and has secured the assistance of the National Academy of Science. The Academy has also recently created a Research Council which is engaged in studying our natural resources with respect to men and opportunities for research, as well as the best methods for its encouragement and for the achievement of greatest productivity.

BIRD MIGRATION

BEGINNINGS OF MIGRATION INTIMATELY CONNECTED WITH PERIODIC CHANGES IN THE FOOD SUPPLY—INTERESTING HABITS OF DIFFERENT KINDS OF BIRDS

BY H. W. SHIMER

THE mystery of bird migration is a source of perennial fascination. It has been a subject for study and speculation from the earliest times. The latest and most authoritative statement on bird migration, dealing especially with North America, was issued last year by the lamented Wells W. Cooke,[1] one of the greatest experts on this subject in the world.

But the causes of migration have yet no conclusive answer. Quoting from Mr. Cooke:

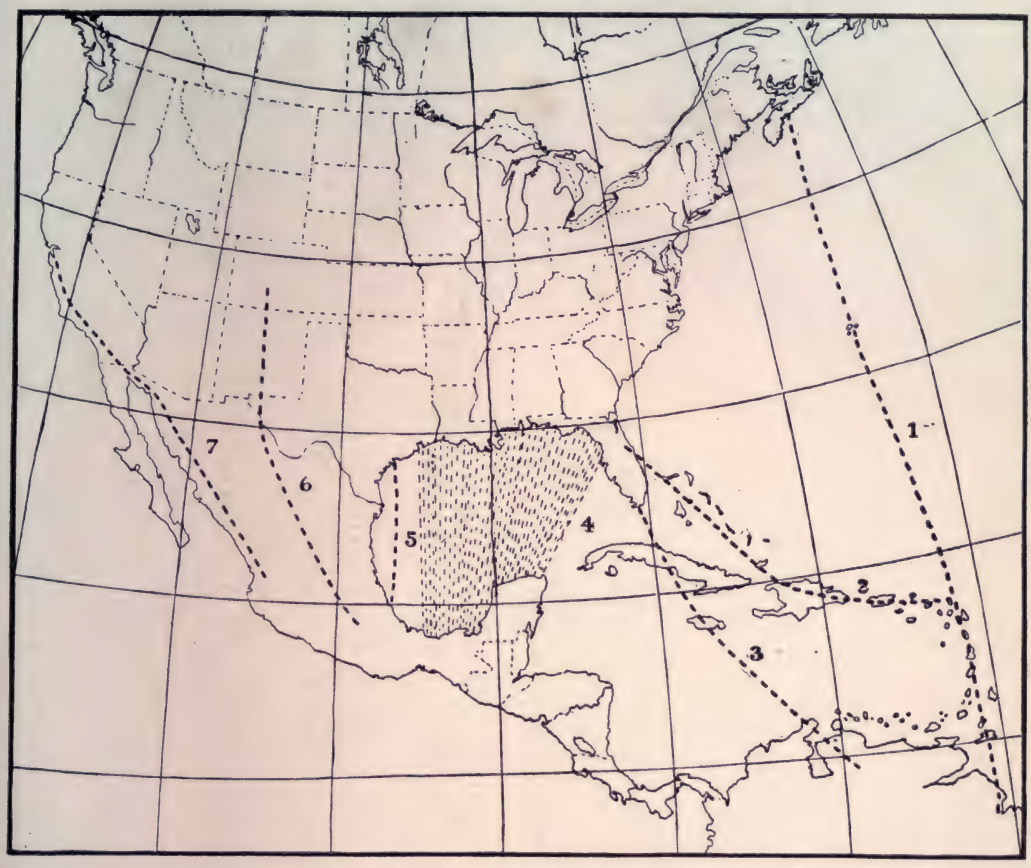
Two different and indeed diametrically opposite theories have been advanced to account for the beginnings of these migrations. According to the more commonly accepted theory, ages ago the United States and Canada swarmed with non-migratory bird life, long before the Arctic ice fields advancing south during the glacial era rendered uninhabitable the northern half of the continent. The birds' love of home influenced them to remain near the nesting site until the approaching ice began for the first time to produce a winter—that is, a period of inclement weather which so reduced the food supply as to compel the birds to move or starve. As the ice approached very gradually, now and then receding, these enforced retreats and absences—at first only a short distance and for a brief time—increased both in distance and duration until migration became an integral part of the very being of the bird. In other words, the formation of the habit of migration took place at the same time that changing seasons in the year replaced the continuous semitropical conditions of the preglacial eras.

Among the theories advanced to account for the disappearance of birds in the fall and their reappearance in the spring were hibernation in hollow trees or in the mud of streams, and wintering in the depths of the seas. With fuller knowledge has come more exact conclusions and it is known now that birds seek a warmer clime during the period of the northern winter.

As the ice advanced southward the swing to the north in spring migration was continually shortened and the fall retreat to a suitable winter home correspondingly lengthened, until during the height of the glacial period birds were for the most part confined to middle and South America. But the habit of migration had been formed, and when the ice receded toward its present position the birds followed it northward and in time established their present long and diversified migration routes.

Those who thus argue that love of birthplace is the actuating impulse to spring migration call attention to the seeming impatience of the earliest migrants. Ducks and geese push northward with the beginnings of open water so early, so far, and so fast that many are caught by late storms and wander disconsolately over frozen ponds and rivers, preferring to risk starvation rather than to retreat. The purple martins often arrive at their nesting boxes so prematurely that the cozy home becomes a tomb if a sleet storm sweeps their winged food from the air. The bluebird's cheery warble we welcome as a harbinger of spring, often only to find later a lifeless body in some shed or outbuilding where the bird sought

[1] "Bird Migration," U. S. Dept. Agric. Bull. 185.



Principal migration routes of North America. Most migrants use route No. 4, though this necessitates a flight of 500 to 700 miles across the Gulf of Mexico. A few traverse the more direct route No. 3, and still fewer, route No. 2

Only water birds (Ex. Golden Plover of the Atlantic Ocean) make the 2,400-mile flight along route No. 1, from Nova Scotia to South America

shelter rather than return to the sunny land so recently left. As a matter of fact, however, only a small percentage of birds exhibit these preseasonal migration propensities. The great majority remain in the security of their winter homes until spring is so far advanced that the journey can be made easily and with comparatively slight danger; and they reach the nesting spot when a food supply is assured and all the conditions of weather and vegetation are favorable for beginning immediately the rearing of a family of young. If, however, a longing for home is considered the main incentive to their northward flight, there arises the question as to why birds desert that home so promptly after the nesting season is over. Data recently collected at the Florida lighthouses by the Biological Survey show that southward migration begins at least by the 10th and probably as early as the 1st of July. Indeed, most birds start south as soon as the fledglings are able to shift for themselves. The orchard oriole, the redstart, and the summer warbler of central United States and the nonpareil of the South all begin their southward journey early in July, long before the fall storms sound a warning of approaching winter and when their

insect menu is particularly varied and abundant.

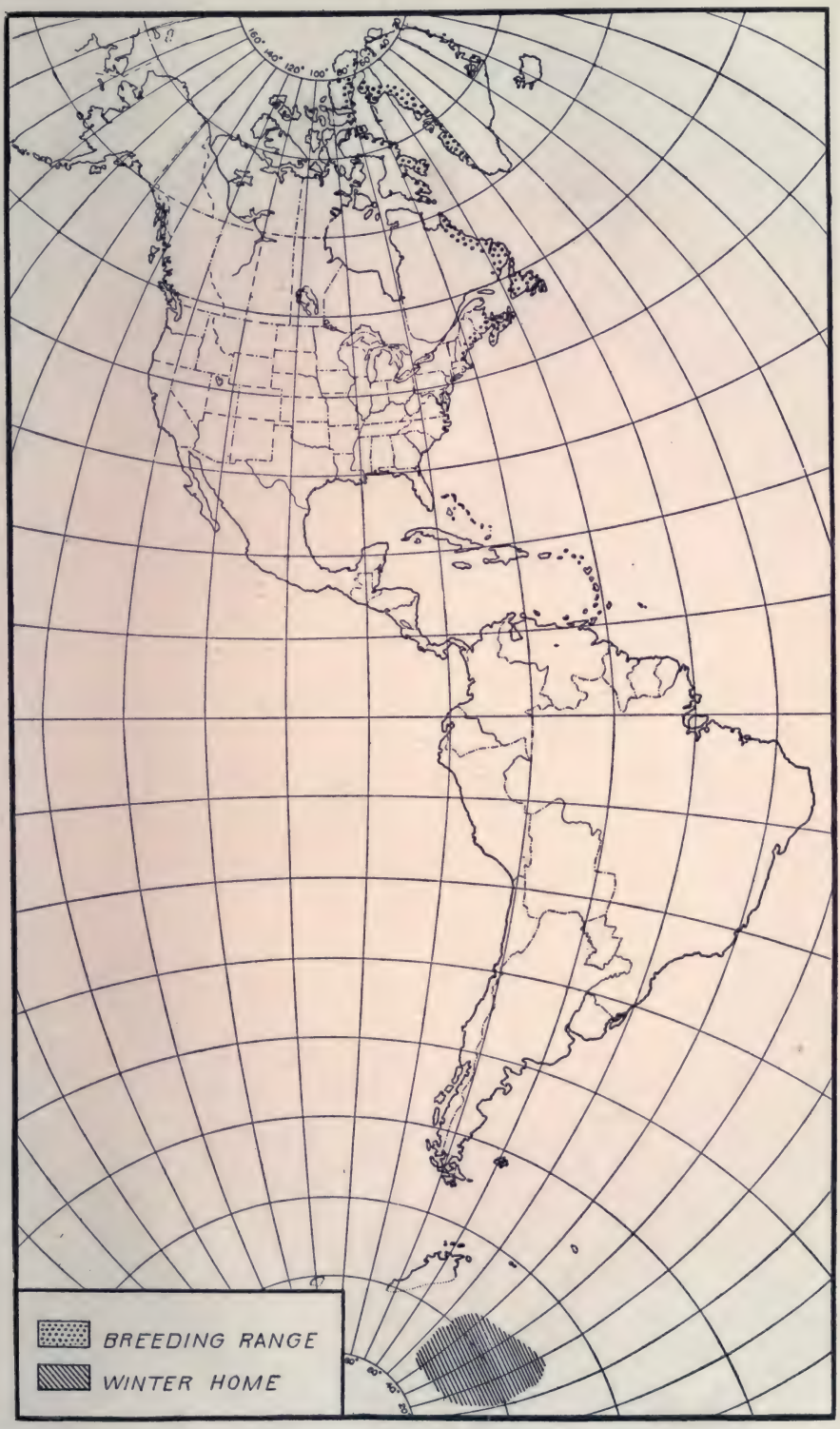
According to the opposite migration theory, the birds' real home is the Southland; all bird life tends by overproduction to overcrowding; and, at the end of the glacial era, the birds, seeking in all directions for suitable breeding grounds with less keen competition than in their tropical winter home, gradually worked northward as the retreat of the ice made habitable vast reaches of virgin country. But the winter abiding place was still the home, and to this they returned as soon as the breeding season was over. Thus, in the case of the orchard oriole mentioned above, many individuals that arrive in southern Pennsylvania the first week in May leave by the middle of July, spending only two and one half months out of the twelve at the nesting site.

Whichever theory is accepted, the beginnings of migration ages ago undoubtedly were intimately connected with periodic changes in the food supply. While North America possesses enormous summer supplies of bird food, the birds must return south for the winter or perish. The overcrowding which would necessarily ensue should they remain in the equatorial regions is prevented by the spring exodus northward. No such movement occurs toward the corresponding southern latitudes. South America has almost no migratory land birds, for bleak Patagonia and Tierra del Fuego offer no inducements to these dwellers of the limitless forests of the Amazon.

The conclusion is inevitable that the advantages of the United States and Canada as a summer home and the superb conditions of climate and food for the successful rearing of a nestful of voracious young far overbalance the hazards and disasters of the journey thither. For these periodical trips did not just happen in their present form; each migration route, however long and complex, is but the present stage in development of a flight that at first was short, easily accomplished, and comparatively free from danger. Each lengthening of the course was adopted permanently only after experience through many generations had proved its advantages.

It may safely be stated that the weather in the winter home has nothing to do with starting birds on the spring migration, except in the case of a few, like some of the ducks and geese, which press northward as fast as open water appears. There is no appreciable change in temperature to warn the hundred or more species of our birds which visit South America in winter that it is time to migrate. It must be a force from within, a physiological change warning them of the approach of the breeding season, that impels them to spread their wings for the long flight.

The length of the migration journey varies enormously. A few birds, like the grouse, quail, cardinal, and Carolina wren are non-migratory. Many a bobwhite rounds out its full period of existence without ever going ten miles from the nest where it was hatched. Some other species migrate so short a distance that the movement is scarcely noticeable. Thus, meadowlarks are found near New York City all the year, but probably the individuals nesting in that region pass a little farther south for the winter and their places are taken by migrants from farther north. Similarly the robin occurs in the middle districts of the United States throughout the year, in Canada only in summer, and along the Gulf of Mexico only in winter. Probably no individual robin is a continuous resident in any section; but the robin that nests, let us say, in southern Missouri, spends the winter near the Gulf, while his hardy Canada-bred cousin is the winter tenant of the abandoned summer home of the southern bird. Among the long-distance migrants are some of our commonest birds; the scarlet tanager migrates from Canada to Peru; the bobolinks that nest in New England probably winter in Brazil, as do purple martins, cliff swallows, barn swallows, nighthawks, and some thrushes, which are their companions both summer and winter. The black-poll warblers that nest in Alaska winter in northern South America, at least 5,000 miles from



Distribution of the arctic tern (*Sterna par-adisaea*), the champion long-distance migrant of the world. It breeds as far north as it can find land on which to build its nest, and winters as far South as there is open water to furnish it food. The extreme summer and winter homes are 11,000 miles apart, or a yearly round trip of 22,000 miles

the summer home. The land bird with the longest migration route is probably the nighthawk, which occurs north to Yukon and south, 7,000 miles away, to Argentina.

But even these distances are surpassed by some of the water birds, and notably by some of the shore-birds, which as a group have the longest migration routes of any birds. Nineteen species of shore-birds breed north of the Arctic Circle, every one of which visits South America in winter, six of them penetrating to Patagonia, a migration route more than 8,000 miles in length.

The world's migration champion, however, is the arctic tern. It deserves its title of "arctic," for it nests as far north as land has been discovered, that is, as far north as the bird can find anything stable on which to construct its nest. Indeed, so arctic are the conditions under which it breeds that the first nest found by man in this region, only $7\frac{1}{2}°$ from the pole, contained a downy chick surrounded by a wall of newly fallen snow that had been scooped out of the nest by the parent. When the young are full grown the entire family leaves the Arctic and several months later they are found skirting the edge of the Antarctic continent. What their track is over that 11,000 miles of intervening space no one knows. A few scattered individuals have been noted along the United States coast south to Long Island, but the great flocks of thousands and thousands of these terns which range from pole to pole have never been noted by an ornithologist competent to indicate their preferred route and their time schedule. The arctic terns arrive in the far north about June 15 and leave about August 25, thus staying fourteen weeks at the nesting site. They probably spend a few weeks longer in the winter than in the summer home, and this would leave them scarcely twenty weeks for the round trip of 22,000 miles. Not less than 150 miles in a straight line must be their daily task, and this is undoubtedly multiplied several times by their zigzag twistings and turnings in pursuit of food. The arctic tern has more hours of daylight and sunlight than any other animal on the globe. At the most northern nesting site the midnight sun has already appeared before the birds' arrival, and it never sets during their entire stay at the breeding grounds. During two months of their sojourn in the Antarctic the birds do not see a sunset, and for the rest of the time the sun dips only a little way below the horizon and broad daylight is continuous. The birds therefore have twenty-four hours of daylight for at least eight months in the year, and during the other four months have considerably more daylight than darkness.

The golden plover of the Atlantic Ocean, though often flying 2,400 miles continuously, from Nova Scotia to South America, could make intermediate stops if they so desired. Sometimes, when storm driven, they seek the nearest land and not infrequently appear at Cape Cod and Long Island. Some flocks stop for longer or shorter periods at Bermuda and on the islands of the Lesser Antilles. To the golden plover of the Pacific, however, no such convenient harbors of safety are available. Their flight of approximately equal length (2,000 miles) takes them across an islandless sea from Alaska to Hawaii. No matter what storms are encountered, when once they are started over the ocean they must continue to the end or perish. It seems incredible that any birds can lay a course so straight as to attain these small islands in mid-ocean, 2,000 miles from the Aleutian Islands on the north, 2,000 miles from California on the east, and 3,700 miles from Japan on the west. And yet year after year golden plover in considerable numbers fly in fall from Alaska to Hawaii, spend the winter there, and the next spring wing their way back again to nest in Alaska.

Food is the principal factor in determining migration routes, and in general the course between summer and winter homes is as straight as the birds can find and still have an abundance of food at each stopping place.

It is interesting to note the relation

between migration and molting. Most birds care for their young until old enough to look out for themselves, then molt, and when the new feathers are grown start on their southward journey in their new suits of clothes. But the birds that nest beyond the Arctic Circle have too short a summer to permit such leisurely movements. They begin their migration as soon as possible after the young are out of the nest and molt en route.

In this connection it may be well to consider the actual amount of energy expended by birds in their migratory flights. Both the soaring and the sailing of birds show that they are proficient in the use of several factors in the art of flying that have not yet been mastered either in principle or practice by the most skillful of modern aviators. A vulture or a crane, after a few preliminary wing beats, sets its wings and mounts in wide sweeping circles to a great height, overcoming gravity with no exertion apparent to human vision even when assisted by the most powerful telescopes. The humming bird, smallest of all birds, crosses the Gulf of Mexico, flying over 500 miles in a single night. As already noted, the golden plover flies from Nova Scotia to South America, and in fair weather makes the whole distance of 2,400 miles without a stop, probably requiring nearly if not quite forty-eight hours for the trip.

Here is an aërial machine that is far more economical of fuel— *i. e.*, of energy —than the best aëroplane yet invented. The to-and-fro motion of the bird's wing appears to be an uneconomical way of applying power, since all the force required to bring the wing forward for the beginning of the stroke is not only wasted, but more than wasted, as it largely increases the air friction and retards the speed. On the other hand, the screw propeller of the aëroplane has no lost motion. Yet less than two ounces of fuel in the shape of body fat suffice to force the bird at a high rate of speed over that 2,400-mile course. A thousand-pound aëroplane, if as economical of fuel, would consume in a twenty-mile flight not the gallon of gasoline required by the best machines but only a single pint.

Interest in bird migration goes back to a remote period; marvelous as were the tales of spring and fall movements of birds, as spun by early observers, yet hardly less incredible are the ascertained facts. Much has been learned about bird migration in these latter days, but much yet remains to be learned, and the following is one of the most curious and interesting of the unsolved problems. The chimney swift is one of the most abundant and best-known birds of eastern United States. With troops of fledglings catching their winged prey as they go and lodging by night in tall chimneys, the flocks drift slowly south joining with other bands, until on the northern coast of the Gulf of Mexico they become an innumerable host. Then they disappear. Did they drop into the water or hibernate in the mud, as was believed of old, their obliteration could not be more complete. In the last week in March a joyful twittering far overhead announces their return to the Gulf coast, but their hiding place during the intervening five months is still the swift's secret.

CALIBRATING SOIL VALUES

The United States Bureau of Plant Industry is proposing a new method of classifying lands in the arid and semi-arid portions of the United States, based upon the indication of the native vegetation. In order to accomplish this, an "indicator" plant is being developed along scientific lines, and it is expected that this plant will show whether the land in question is suitable for dry farming and whether the amount of alkali present is sufficient to injure crop-plants under irrigation. Investigations along these lines are being carried on in Southwestern Utah, Southern Nevada, Southern California and Southern Arizona.

If the bureau is successful in developing a plant that covers the requirements, the results will be of enormous value to the country.

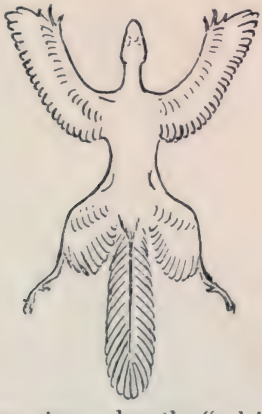
THE BEGINNINGS OF FLIGHT IN BIRDS

EVIDENCES OF A PREHISTORIC PELVIC WING SHOW THAT BIRDS WERE ORIGINALLY GLIDERS AS WERE THE FLYING MAMMALS

BY H. W. SHIMER

FREEDOM of movement through air or through water presents somewhat similar problems. The fish have solved the latter by means of fins and tail, birds and bats the former by wings. These structures are the resultant, however, of many experiments; it is the various stages leading up to the present condition that are interesting. In fish there is considerable evidence that the pectoral and pelvic fins arose from an earlier horizontal fold extending from the gills to the tail. In bats and other flying mammals and reptiles a similar horizontal fold extending along the sides of the body between the fore and hind limbs and tail represents the beginning or in most the only flying structure. Did the wings and tail of birds have a similar origin, or were they always as distinct as at present? A partial answer to this was discussed by C. W. Beebe,[1] and by F. A. Lucas[2] in some late publications.

Archaeopteryx stage, when the wings were increasing in power and the "pelvic wing" was going into disuse



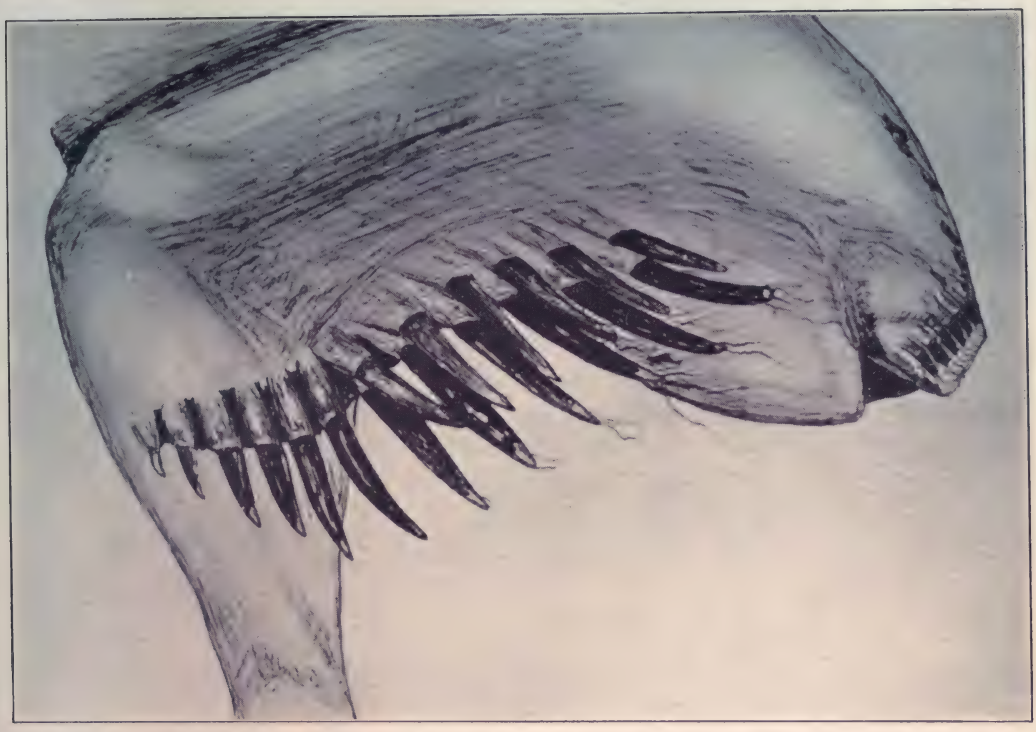
Tetrapteryx stage, when the "pelvic wing" of birds was at its height of development and use

Mr. Beebe noticed certain feathers on the hind limbs of newly hatched modern birds of several species which he suggests might have functioned as a posterior or pelvic pair of wings in their Mesozoic ancestors. These feathers, reduced now to a series of sprouting quills, extend from the upper part of the leg just below the knee, nearly to the base of the tail, while just above and alternating with them is a series of quills placed precisely like the upper wing coverts.

This modern bit of evidence is corroborated in the earliest known fossil bird, Archeopteryx, from the Jurassic of the middle Mesozoic era of earth history. As to whether still earlier forms possessed a row of feathers connecting fore and

[1] "The Tetrapteryx Stage in the Ancestry of Birds" by C. W. Beebe, curator of birds in the New York Zoölogical Park, published in *Zoölogica*, Vol. 2, No. 2, 1915.

[2] "The Beginning of Flight," *The American Museum Journal*, Vol. 16, pp. 5–11, 1916.



"Pelvic wing" of the squab of the white-winged dove, consisting of twelve flight feathers and six coverts. These feathers develop on the young bird while the body is yet bare except for the flight feathers of wing and tail. (By courtesy of the New York Zoölogical Society)

hind limbs, no evidence is at hand. During this four-winged stage, which Mr. Beebe calls tetrapteryx, the bird, like the flying squirrel of today, was a glider with fore limbs, hind limbs and tail held perfectly rigid. Only later, probably before the time of Archeopteryx, did it begin to wave its fore limbs, thus causing them to develop rapidly into a functional wing. At the same time the pelvic wings, to quote Mr. Beebe "would become more and more reduced."

In the words of Mr. Lucas: "Having arisen from among the surrounding scales, they had for a time volplaned through the air of early ages, a structure passive and, as future centuries would show, of merely transitory function. Yet they were of tremendous importance in allowing the pectoral scales to develop, to become feathers, and then to assume an importance which was to make the class of birds supreme in the air. Yet the function of the pelvic wings had been so passive and negative that no special muscling had been necessary, no increase or coalescence of bony tissue. Little

A later stage when there has begun a shortening of the tail and concentration of the tail feathers

BERLIN SPECIMEN OF FOSSIL ARCHAEOPTERYX, THE EARLIEST BIRD KNOWN. The feathers on wings and tail are observed at once but those on the hind leg are not noticeable unless attention is called to them. Authorities in the past have thought that these leg feathers functioned little in flight

A Possible Ancestor of Modern Birds. This drawing of the Tetrapteryx stage in the ancestry of birds is based on characters in Archaeopteryx and in the young of modern birds. There are two principal theories as to the origin of flight, one that it was brought about by jumping up, the other by jumping down or volplaning from trees as does the flying squirrel among mammals today. (By courtesy of the New York Zoölogical Society)

by little the line of feathers and their coverts sank into insignificance and became lost among the body plumage."

The bird as we know it today, with no trace of the "pelvic wing" except in the very young bird. (Diagrams reproduced through courtesy of the New York Zoölogical Society)

White-winged dove four days old, with wing and leg extended, the latter to show the feathers of the "pelvic wing." (By courtesy of the New York Zoölogical Society)

VALUE OF LIGHTNING RODS

The United States Weather Bureau has been making experiments on the efficacy of lightning rods on farm buildings, and the results apparently give striking evidence of the value of these rods. In the years 1912 and 1913 about two hundred mutual companies doing about three hundred million dollars' worth of business, reported 1,845 buildings struck by lightning, of which only 67 were equipped with lightning rods. Inasmuch as about a third of the insured buildings are protected by lightning rods it is evident that if they had furnished no protection the number of rodded buildings struck would have been 572 instead of 67. These figures would appear to give an efficiency of 90 per cent. to the rods. Five companies with over eighteen thousand buildings insured, half of which were equipped with lightning rods, report that they had never had a building burned or even materially damaged by lightning that was thus equipped. Their records cover periods ranging from thirteen to twenty-five years. It also appears from the figures of the Bureau that when a building equipped with a lightning rod was struck and damaged but not burned the damage was much less than in unrodded buildings.

AN IMPORTANT ALLOY

The new alloy discovered by Charles E. Guillaume of France promises to be of great service especially in connection with instruments of precision.

This alloy contains approximately 63.8 per cent. iron and 36.2 per cent. nickel, and is characterized by possessing an extremely small coefficient of linear expansion, about 0.0000004 per degree Cent. Within the limits of atmospheric temperature change, its expansion is very exactly proportional to the temperature. It has a modulus of elasticity of about two thirds that of steel, and its hardness is greater than that of hard brass. Invar has found a wide application in metrology and horology. In the former, it is particularly useful for secondary standards of length, and in the latter it is employed for pendulum rods, compensating devices for torsion pendulums and balance wheels.

MYSTERIES OF ULTRA-VIOLET LIGHT

Ever since Professor Becquerel showed the wonders of ultra-violet light, the science of physics has steadily day by day added more and more wonderful knowledge to the subject.

It was until recently thought that the curious chemical action of the ultra-violet radiations were peculiar to it; that negative and films and photographic plates were acted upon solely by the chemical powers of the ultra-violet light. Now, however, it is known that red, blue, infra-red, yellow, green, and the other kinds of light all have chemical powers of more or less strength. These chemical influences will also act upon a film or plate and yield a photograph.

Recently much credence has been given to the proposal of such distinguished savants as Professor Svante Arrhenius of Stockholm and Dr. Thomas S. Blair of Philadelphia that cosmic dust, shooting stars, meteors, comets, and the like carry life from planet to planet. That the germs of life of minute animals and plants have their origins in some such fashion as that.

Now it is known that the ultra-violet rays when directed for varying periods of time from an hour to several hours will kill all life. It is also realized and admitted by all physicists that outer space is permeated by ultra-violet light.

Therefore, say many who jump quickly at conclusions, it is manifestly impossible for life to be transmitted from planet to planet and star to star as these noted investigators maintain.

Yet stop a while! Newer investigations just announced by the illustrious Dr. Alphonse Berget show that Dr. Blair, Professor Arrhenius, Dr. Ecree, and others who hold that the specks of life are thus sent by the Creator from star to star are feasible in every way.

Ultra-violet light like gravitation is weaker and weaker the farther you get away from any spot. Therefore, 93,000,000 miles of separation between the sun and the earth weakens the ultra-violet rays very much. Moreover, and this is the important point, the ultra-violet rays really act by "rusting," "burning," or "oxidizing" the things acted upon. That is to say they kill and exert a chemical action by virtue of the oxygen in the air.

Since there is no oxygen or atmosphere out in space, since it takes some hours for ultra-violet rays to kill; since also a meteor full of life bursts through the atmospheric corona or envelope of the earth in a flash, it follows that life could thus be transmitted through space without trouble to the scientific mind.

Further than this, Professor Roux, another French research student, put living spores in a vacuum—a jar freed of all oxygen and air—and kept these minute living things exposed for six months to ultra-violet light, and they were alive at the end of this time.

All of which goes to show that it is not beyond the bounds of reason, religion, or raving to maintain that life came to the earth through the travels of scurrying "vitality" from world to world on the saddle of comets, cosmic dust, and meteors.—Dr. L. K. Hirshberg in *Scientific American*.

ANIMALS HAVE OUTSTRIPPED PLANTS

Practically all advance depends upon external stimuli. Our bodies feel better, are healthier, when frost in the air stimulates the various organs to greater activity. The principal effect of the morning cold shower is this stimulation of body organs. The principal stimuli to saving is the thought of dependent ones, sickness or old age. Competition stimulates trade as it likewise does intellectual activity. What is true of man is similarly true of all animals and of plants. Just as a continuous application of uniform external stimuli will change man's habits, so similarly changed habits in other animals and plants will in a succession of individuals bring about physical changes.

A "thick-skinned" man can be affected by stimuli and hence have his habits

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changed much more slowly than one of a nervous temperament. The stimuli, which cause the change, can penetrate the latter much more readily than the former. Similarly those organisms which surround themselves with a stimulus-resisting coat will change but slowly.

In both plants and animals the only living matter is protoplasm, a gelatine-like substance chemically composed of water, proteids, carbohydrates, fats and some mineral salts. In plants this protoplasm is completely enmeshed in the woody-fiber, cellulose. In such animals as the snail and chambered nautilus the hard, lime shell covers only a small portion of the soft body surface, except when danger threatens, at which time the animal withdraws within its shell and is thus fully protected. Stimuli from without can thus affect the living protoplasm, that is, the real organism, much less readily in plants than in mollusks. And since it is these same external stimuli when uniformly applied which may bring about changes in the animal or plant structure, plants must of necessity change much more slowly than animals. Also those animals, as the snail and nautilus, which move about in search of food, receive a greater variety of stimuli than do those which, like the corals, or like plants, are stationary.

The different degree to which stimuli may affect plants and freely moving animals is roughly measurable. Among both plants and animals certain forms have evolved a protecting covering for the very young organism. This is illustrated by the acorn and the hen's egg. Most probably plants and animals began their existence upon this earth at about the same time and being derived from the same ancestral plant-animal stem they should have developed this very useful embryo protection at about the same time. We find, however, that the animals, in the sea-snail and nautilus-like forms, had developed this far back in the Cambrian time of earth history, while plants waited until the Comanchean time. This difference in time between the Cambrian and Comanchean, some fifty million years, represents the difference in the accessibility of external stimuli to the living protoplasm plants and animals. H. W. SHIMER.

CHIEF among the discomforts of aviators in the high altitudes are cold hands and feet, and, indeed, in some cases the hands become so numb that they do not properly respond in manipulating the levers. This deficiency is being met by a manufacturing concern which is putting out electrically heated gloves.

SCIENCE CONSPECTUS

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SZECHUEN, CHINA'S WESTERN PROVINCE

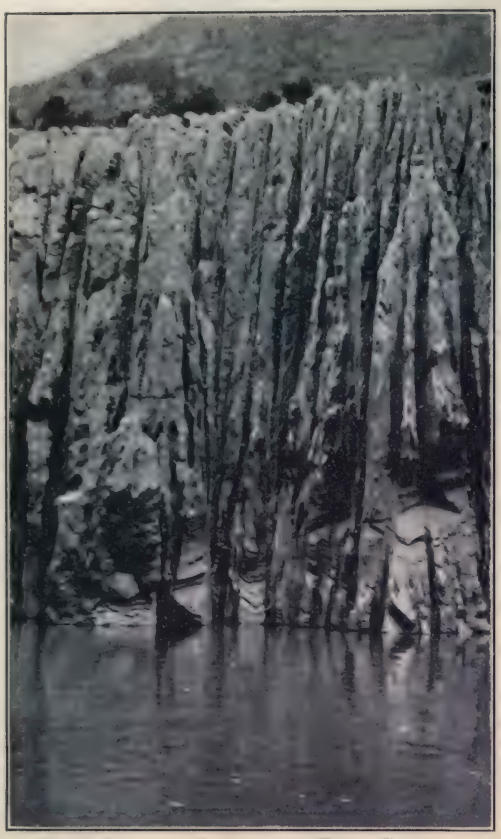
THE PEOPLE, INDUSTRIES AND LIFE OF THIS LITTLE-VISITED COUNTRY, WITH ITS CURIOUS MINGLING OF ANCIENT CUSTOMS AND PROGRESSIVE IDEAS

BY H. K. RICHARDSON

SITUATED at the most western part of China proper is the province of Szechuen, the largest, most populous and the wealthiest of the eighteen provinces of China. The province has an area of 218,533 square miles and a population estimated at 55,000,000,[1] the province thus corresponds roughly in area and population to Germany.

The name "Sze Chuen" means the "Four Rivers" the province taking its name from the fact that it serves as the watershed for four rivers which united leave the province as the Yangstze River. The province is all hills, none of which are below 2,000 feet and some on the Thibetan border reaching 16,000 feet above sea level. The only low land is on the river bottoms and these are narrow. The only plain of any size in the province is the Chengtu plain about forty miles wide by seventy miles long situated near the centre of the province. This plain is 2,500 feet above sea level at the northern end and 1,600 feet above on the southern side, and is the seat of the most wonderfully successful irrigation system that the world has ever seen. This plain is surrounded on all sides by mountains. Along the foot of the mountains on the western border of the plain flows the Min River one of the tributaries of the Yangstze. Originally this river watered only its own little valley and was a wild uncontrollable torrent in summer. About 200 B.C. two Chinese, Li Ping and his son Li Ri Ping conceived the idea of making this river water the whole plain. To this end they cut a gorge in the northern barrier mountain at the city of Kwan Hsien and made an artificial branch to the river. This branch they led across the northern side of the plain and subdivided into many smaller streams, these smaller streams are inter-connected with ditches until the whole plain is interlaced with canals and ditches, distributing the water by gravity to practically every acre of the plain. These ditches and small rivers converge near the southwestern corner of the plain and the unused water rejoins the main stream at Chiang Koand passes on down the Min River to the Yangstze. As an illustration of the foresight and thoroughness of the two engineers, they had two large iron bars weighing 1,500 pounds apiece placed in the bottom of the river at the point where the artificial river leaves the main river. Tradition has it that Li Ping left instructions that each year the river bed must be cleaned out until these bars were reached or there would be dan-

[1] This is an average based on several widely varying estimates.



Eroded river bank, Yangstze River Gorges

Looking into Bamboo Suspension Bridge, Kwan Hsien Sze

Bottom of the well. Salt Spring on river bank. Kwei Chow Fu. The supply was running low so every one was hustling to get more than his share. The men on bottom step are naked and pour into the carrier's buckets

ger of flood the next summer. At the present time contractors must clean the river until these bars are laid bare or the officials will refuse to pass the work. One of the present bars dates from A.D. 1576 and the other from A.D. 1865. For the control of the whole system Li Ping left the six character motto which is translated "Keep the channels deep and the banks low," pretty good engineering advice for B.C. 200 or A.D. 1916. Since the completion of this irrigation system there is no recorded famine nor serious lean year among the inhabitants of the plain and the plain not only supports its own 3,000,000 people but supplies rice to much of the surrounding mountainous country. Due to the abundant supply of water and the warm climate, never freezing and nearly a hundred Fahrenheit in summer, the plain is a veritable evergreen garden the year around. A view from the Kwan Hsien Hills out over the plain on a clear day as the rice fields grow yellow among the bamboo-surrounded farmhouses is a sight never to be forgotten.

It is recorded in the history of the province that in the latter days of the Ming dynasty (A.D. 1650), a serious rebellion broke out in this province against the rulers. The Mings, powerless to cope with the trouble, called upon the Manchus to help them. The rebellion was put down with such destruction of life and property that a census taken in A.D. 1710 gave the total population of the province as 144,154. To this day big mounds called "The 10,000 people's graves" are pointed out to one as a memory of what happened at that time. The big province could not be left desolate so the Manchus had recourse to forced emigration from the other provinces to Szechuen. Today it is hard to get a Chinese to acknowledge Szechuen as his native province, to the question as to how long he has lived in Szechuen you will get the startling answer, "over two hundred years" which interpreted in the light of the history given above means that his ancestors came from one of the other provinces at the time of the forced emigration early in the Manchu dynasty. This mingling of the people from so many of the different provinces has tended to make a more progressive and independent type of Chinese than is met with on the coast. It is rather surprising to some people in view of the poor communications that Szechuen has with the rest of China to find the most naturally progressive Chinese so far in the interior, but the little history given illuminates the reason.

Scattered along the western edge of Szechuen, hemmed in on all sides by the Chinese are remnants of the tribes from whom the Chinese took the country when they came to Asia. These aboriginal tribes while nominally subject to Chinese authority preserve at the centre of their section all the old tribal authority and have their own kings. Only the fringes and a few of the weaker tribes are under complete Chinese control. Unless the tribesmen break out and raid the Chinese community they are left much to themselves. There are several races of these aborigines, the most important are the Lolo in the south and the Hsi Fan in the north. The territory of these two races borders on Thibet and has been little explored by white men, in fact to attempt to pass through one section of Lolodom is almost certain death, for Chinese or foreigner. There is a striking resemblance between these tribesmen and the American Indian in both color and figure. The men are tall, magnificent specimens of humanity while the women are short, slender and less bronzed than the men. The various races dress in a coarse cloth like gunny sacks, but the different tribes are easily distinguishable by the cut and color of the clothes. Some missionary work is being carried on with success among the Miao tribe on the Yunnan border. This tribe is under subjection to the Chinese and are treated as inferiors, they feel their degraded position so keenly that they welcome the hope that Christianity brings them. No census has ever been

Terraced hillsides. Rice fields. Water standing in field. Stair-case farms

taken of these people but they cannot be far from 2,000,000 in number.

Like all parts of China the most important work of the Szechuenese is the growing of foodstuffs. In Szechuen rice is the standard and basic crop. Wheat is grown in large areas but is of far less importance than the rice. The diet of the average coolie is steamed rice, green vegetable and bean curd. A little pork once a month will be all the meat the family will have. The vegetable is prepared by first frying in lard or a vegetable oil obtained from the seed of a species of cabbage plant, then adding water and boiling the whole to the consistency of stew. Salt and red pepper are used as seasoning. The bean curd is made by grinding up beans and water to a paste, then settling out the curd with a solution of gypsum. The curd after separation from the refuse is molded into bricks which when cold are cut into convenient sizes and either boiled in the vegetable or smoked over the coals. The curd is greyish in color and about the consistency of new cheese. Variety in the diet is obtained by a variation in the kind of green vegetable used, and vegetables are fresh at all times of the year.

The Chinese eating habits are different from ours, for each person is supplied with an individual rice bowl, while the soup, vegetable and meat are placed in common bowls in the center of the table and everyone reaches for what he wants with his own chopsticks. The wealthy families follow the same general habits of diet, except that they have more meat.

On the Chengtu plain there are three crops a year, two main crops and a crop of small vegetables. The spring crop is planted in November and harvested in April. About half of this crop is wheat but hemp, ramie, the oil plant, tobacco or beans are planted in special localities. The summer crop is always rice. It is transplanted to the plowed fields as soon as possible after the spring crop has been harvested, but not later than the middle of April. The crop is cultivated twice at intervals of fifteen days, the water being run off only during the time of the cultivation. In the latter part of August the water is run off the fields so that the ground will harden and the grain stand erect. Early the first week in September all the fields will have been reaped. After this some farmers will get a crop of radish or other

Raising water from one field to another by chain pump. Dragon bone lift. Note main road on top of the terrace (the stone slabs)

small vegetable from the ground in the next two months. The rental of the land is paid from the rice crop, usually sixty per cent. of the hulled rice is the price. The spring crop and small vegetables belong to the tenant. A first class piece of land will give 160 bushels of rice per acre, or about 6,400 pounds of shelled rice.

On the hillsides of the province and places not reached by the irrigation system about one-half of the fields are reserved for rice. These fields are not cultivated for a spring crop but are allowed to accumulate water during the winter rains, this insures that there will be water enough to plant at least these fields to rice in the spring. The loss of the wheat crop that might have been grown during the winter is never considered, for a shortage of rice is the serious thing and its occurrence cannot be risked.

The importance of the rice crop is better appreciated when we know that the average Chinese eats ten or eleven bushels or over 400 pounds of rice per year. The rice bill is from sixty-five to eighty per cent. of the cost of a coolie's food. The cost of food in the majority of Chinese homes is one-half the total cost of living. To guard against shortage in the rice supply and to be prepared for siege every district city has an official granary, which in a medium sized city will have a capacity of three hundred thousand bushels. In case dealers manipulate the market too much and send the price so high that there is danger of riots, the official must start selling from the oldest grain stored and hold the price down. He must replace that which was sold just as soon as the new crop is available.

The hillsides are made available for rice cultivation by the process of terracing. To keep water on the rice it is needed that the plot of ground be approximately level. To accomplish this the hillsides are cut away in steps and the little plots are built one above the other like stairs. As the soil is clay there is little need of stone except in a place where the rains wash badly. These hillsides, which are called by some staircase farms, are better called staircase gardens for there is hardly a plot that is as large as a quarter of an acre. To bring the water from the lower steps to the higher the Chinese have several very ingenious

systems, the one most commonly seen is the dragon bone lift, which resembles a chain pump. It is a kind of a wooden endless chain on which are placed wooden pieces. These pieces fit closely into an open trough, open at the top and bottom. A man standing on the axle of a notched wheel revolves it towards him, the chain is carried over the wheel and the wooden pieces enclose a little water from the bottom pool and carry it up the trough and discharge it at the top. It is slow work but time means nothing to the coolie.

Among the higher hills where rain must be depended upon for water the staple crop is corn. In these hills the land is not terraced and sometimes a farmer can be seen cultivating a field that has nearly a forty-five degree slope. The hill farmer imports rice from the plain to serve as the basis of his meal, using the corn to piece out.

All over the province there are medicinal plants found but the larger amounts collected for export come from the Thibetan borderland. Some $1,000,000 worth of these medicines pass through the customs each year. It is said that there is a larger variety of flora found in this province than in any equal area in the world.

In common with other parts of China the industrial life of Szechuen is many years behind the developments in Europe. Szechuen is now at about the same stage industrially that England reached three hundred years ago, only China reached that same stage centuries ago. It is rather startling to realize that the silk looms, houseboats, grinding apparatus and in fact nearly all the strictly Chinese things we see on the street are made today on the same pattern that they were two thousand years ago. Considering the early date at which these implements were perfected one cannot but marvel at the ingenuity shown. It has been found that the houseboats that make the trip up the Yangstze gorges are much better and safer than a modern type boat, and the hulls of the most successful steamers that make this run are now being built on the lines similar to the old houseboat.

The silk industry is one of the most important to Szechuen. The abundance of mulberry trees makes the process of feeding the worms an easy matter. Nearly every household will hatch a few worms and it is no unusual sight in the season to see the women looking at the eggs hatching in their bosoms. Like all home industries the silk industry is carried on in full view of the street. All the operations of reeling, dyeing and weaving can be seen any day on the street. Perhaps the most interesting operation to watch is the weaving, for seated on an elevated bench over the looms is a boy who pulls the pattern strings for the flowered silk while his comrade works the shuttle. It is a wonder that he makes so few wrong combinations. The loss of much of the foreign trade in silk to the Japanese has spurred the Chinese on to improve their methods so that their product will compete with the finer grade Japanese product. The government of Szechuen has established silk worm culture schools at several places in the province. Also there are one or two reeling factories under government control, where with simple wooden machinery a much better grade of raw silk is made than in the home. The apprentices in these plants learn the whole process and are given a little common school education as well so that they will be able to start small industries when they are through. The work is self-supporting as the product pays all expenses and yields a profit to the government. In addition there is one steam filiature under private management that supplies first class silk to the foreign market. To supply the needs of the province considerable of the raw silk is woven into crêpes and satins. It is estimated that about $5,000,000 worth of silk is exported yearly from the province and that a like amount is consumed locally.

Along the river bottoms there is considerable land that is favorable to the

Coal carriers, Kwan Hsien Hills. Large load 330 pounds. Carriers get about 8 cents for a five-mile trip. Path is down through a cornfield

production of sugar cane. It is estimated that over 300,000 acres are planted to cane each year. The planting is done in February and the cutting in November. In every sugar cane section there are a number of crude juice extracting mills and evaporator houses. The crude sap is boiled down to the consistency of soft maple sugar, and sent to the refinery if white sugar is wanted, or sent to the city and sold for candy making or cooking. Most of the buyers prefer the crude sugar as the molasses it contains helps in the making of candy. Sugar sells for about six cents a pound which makes it a luxury when we think that the daily food of the ordinary man will cost only three cents.

An ordinary laborer receives six cents a day if he "eats himself" (*i. e.*, buys his own food) and must support his family on that. A skilled carpenter is extremely fortunate if he gets ten cents a day. I have hired many of the best men at $2.00 a month which was better than they could have got at other places. For this they would have worked thirty days from sunrise to sunset, with only two meal times and two recesses for smokes, if our policy had not been no Sunday work. The Chinese workman does not have a Sunday rest, his only holiday is a week at New Year, and the fifth and eighth month feast days. At these times it is the custom of Chinese employers to give a small present of half a month's wages for the three occasions to their workmen.

Of all the native industries the salt industry has brought out the best of the ingenuity of the Chinese. Salt is recovered from brine, which is obtained from the earth in three types of wells. First the open well dug some thirty feet deep to uncover a salt spring as at Kwei Chow Fu, the second where the well is driven through a bed of clay and a little stone to a depth of 1,000 feet and the third the wells driven to a depth of 4,000 feet through a soft sandstone as at Tzu Liu Tsing. In case of the first sets of wells the brine is brought up the steps of the well in buckets by coolies and transported by sluiceways to the open evaporating pans fired by coal. The water is evaporated off until a six inch layer of

Salt wells at Tzu Liu Tsing, Szechuen. Bamboo pipe lines in foreground. The houses illustrate the usual type of construction, wood with plaster panels

salt is left on the pan, when the cake is removed, broken up and sold. The culm from the coal is mixed with clay and makes a good briquette. The second type of well is found all over the province and is recognized by its fifteen foot winding drum. In these wells the brine is raised by means of a bamboo tube or bailer, put into buckets and sent to the nearby evaporator house to be made into pan salt. The motive power for the drum is human labor, a cow or a buffalo according to the section and the wealth of the farmer.

The deep wells are all situated at Tzu Liu Tsing and are the most numerous and productive in the province, if not in China. It has been estimated that over ten thousand wells have been driven in this territory, of which five thousand are in active operation today, while some few hundred are still in the drilling stage. The territory is very hilly and comprises three market towns under the government of two separate districts. All the wells are within an area of fifteen by three miles. The town supports a population estimated at one million, who think, dream and live by salt. The existence of this large city is not suspected by one outside of Szechuen. Every day in the year one can see a stream of coolies carrying salt away by every road, while boat loads are leaving continuously for down the river. Over 200,000 tons of salt are officially known to leave the town per year and the salt office fails to get a large amount that is smuggled away. One thousand tons a day would not be far from the daily production of these wells, which is a large industry for China. In all the wells the brine is brought to the surface in long bamboo tubes, 110 feet long, and sent by way of bamboo pipe lines to the natural gas wells to be evaporated. The pipe lines are operated by gravity and the idea has been in use for over a thousand years. The business hustle of this town, the noise of the many derricks, the sight of the pipe lines and the sky line of derricks make one think of a thriving oil well district in United States and not of China. The salt wells have made more millionaires

than any other thing in Szechuen, and Tzu Liu Tsing is the home of them all.

Szechuen is the home of the remarkable ch'i tree, the tree from which the wonderful Chinese lacquer is obtained. From the sap of this tree the Chinese make a varnish or lacquer that dries on a wet hot day to a beautiful gloss surface. It will not scar if hot boiling water or hot dishes are placed on it. It is used on all table tops because it does not scratch easily.

Most of the China wood oil now so much used in varnish in the United States comes from this province. The nuts from which the oil is expressed are rid of the fleshy exterior, ground shells and all, then heated slightly and the oil expressed in a crude wedge press. The oil is transported in woven bamboo baskets lined with paper, to the collecting depot, where it is sent to Hankow for trans-shipment to United States. The government is encouraging the planting of these trees, as all the nuts now obtained are from trees that sprung up of themselves.

A description of Szechuen is incomplete without a word or two about Chengtu, the capital of the province. The capital is situated in the centre of the Chengtu plain and is usually approached along the east road. The city itself is planted full of trees and bamboos and cannot be seen or distinguished until the very walls are reached. These walls dating from the time of the early Manchu dynasty, A. D. 1680, are made of brick upon a sandstone foundation backed by an earthern embankment some thirty feet deep. The walls are thirty-five feet high and twelve miles in circumference, and are paved with brick on the top of the earthern embankment, making a fine promenade. The walls are pierced by four gates outside of which are four suburbs built along the roads leading to the gates. The suburb along the east road is five miles long and looks like a continuous town the whole length. Outside the city on the plain wheelbarrows are used to transport coke, pigs, manure and passengers. Sometimes it is a mixed load but more often the passenger has a seat fixed in front of the high middle wheel.

Entering the city the first time, a foreigner is asked by the police at the gates for his card, what his business is to be in the town, how long he expects to stay and how many pieces of luggage he has; this over he passes into the city and his baggage is passed along as it arrives. Not so fortunate is the native, for before he can enter he must have every box opened and examined. Likin or duty is charged on things innumerable and as every city is a law unto itself one can imagine the inconvenience caused a Chinese who does much traveling, in fact no one but a Chinese would have the patience to submit to such treatment.

The main street just inside the East gate is the widest and most important business street in Chengtu. Here are to be found the silk stores, stores which sell foreign things; although the Arcade a few blocks away, a covered cross street, is the headquarters for foreign goods; and most of the silversmiths. The shop signs are all hung vertically and are taken in at night so as not to be lost. In the evening after the shop fronts are put up this street is the scene of a street bazaar; many small dealers in curios, bone, baskets, socks, boxes and trinkets squat along the edges of the street in front of the shops and sell their goods by the weird light of the candles or oil lamps. Every other business except this and the tea-shops close at dark. Scattered among the other shops at convenient intervals are the cash shops or the money exchangers, a most necessary institution in these days of monetary chaos. In every-day transactions amongst the coolies the old cash or the coin with the square hole is the standard of reckoning. None of these "cash" are made today but to facilitate matters the provincial government has coined brass pieces that represent ten, twenty, fifty and one hundred cash but which contain brass in diminishing proportion. Side by side with this brass is a silver coinage used by the government, wealthy Chinese

Nut grinder or rice huller. All the nuts for the China wood oil sent to United States are ground in this type of apparatus

and the foreigners. Between these two coinages there is an ever varying daily exchange; in two years the value of a silver dollar has varied from 1,200 to 1,700 of the small cash. Add to this the military notes with their fluctuating value and you can appreciate the question asked of a Chinese friend "Is it the monetary system of the Chinese that made them such gamblers or vice versa?" Szechuen, be it said to its credit, has the simplest monetary system of any of the provinces of China.

All shop fronts are open to the public and the wares exposed to inspection, so one can tell at a glance what the shop has to offer. Most of the stores are of a standard size, one section, twelve feet wide by fourteen feet deep. Behind the store room is a room for the family with perhaps a loft above for the apprentices to sleep. Including the shop the usual family will have about six persons in a space fourteen by twenty feet and all the family activities will go on here. The shops are built tight up to each other, in country, or city, so that light and air only come in the shop front and the back door, if there is one. At night the only air that can get into the rooms is that which leaks in through the cracks, so the prevalence of consumption is easily explained. These crowded quarters naturally force many of the family activities into public view. It is a common sight to see the family eating their meals, the youthful members of the family being disciplined, the children being nursed, or the family quarreling right in public view. If any repairs are needed in the house the carpenter and the mason will do their work on the street, all passers-by good-naturedly move around the mud-pile of the mason and the wood of the carpenter even though they take up half the width of a twelve-foot street. The lack of house room is a nuisance when one of the family dies and it is necesssary to have a funeral feast and rites over the dead one. The difficulty is solved by extending a temporary platform out into the street in front of the shop about eight feet and surrounding it by mats. It makes little difference to the family that they have reduced the street to its lowest dimensions

Court yard of the "Great Prosperity Inn" Kuan Yuin Chiso, Szechuen. (H. K. R.'s carriers and baggage in the yard ready for the night)

and traffic moves as over a single track railroad. These little matters of inconvenience are overlooked by the good-natured Chinese for it is the custom to do so.

All the streets in the city and the principle country roads are paved with stone slabs. The streets in Chengtu are kept tolerably clean and the city has the reputation for having the cleanest and widest streets of any real Chinese city except Peking, in the republic.

Passing along the street in a sedan chair you will sometimes find yourself set over the goods in a shop. Looking ahead you will see a big box taking up nearly the whole street slowly approaching. As it comes nearer you will discover that there is a man under the load which is strapped to his back. As he slowly waddles down the street everything and body must turn aside so he can have the whole street. These men can carry a whole parlor suite at once and one load will move a coolie family, cupboards and all. In the mountains, they carry 350 pounds about twenty miles a day.

All the little shops seen along the street are built on the front edge of the lot of land belonging to a wealthy Chinese. Behind these shops he builds his "gung gwan," a house built around two or three courtyards and back away from the street. In the rear will be a garden, a rookery or a pond. The whole lot will be surrounded by a compound wall ten feet high and eighteen inches thick which keeps him and his family secluded from the neighbors. It is the custom of every Chinese family to keep their girls in seclusion from the age of twelve until they are married at from sixteen to twenty, although some are "sent out" (married) at fourteen or fifteen. The compound wall helps in making this seclusion possible. This seclusion of unmarried girls is one of the reasons why there is so little immorality in a purely Chinese city. It is a rare thing for a Chinese girl to go astray for she is watched so closely. All the prostitutes are slave girls bought in their youth from poor parents and brought up into the life.

Foreigners living in interior cities live in compounds like the wealthy Chinese

and the interior can be arranged to be as much foreign as is wished, only when one goes on the street would he know he were in China, for the seclusion of the compound wall is well nigh complete.

Perhaps some one will wish to take the trip to Chengtu as a summer vacation trip; it will be one of the rarest treats he has ever had. Leaving Shanghai, the first stage, 600 miles up the broad and muddy Lower Yangstze to Hankow the Chicago of China, is made in some of the finest river steamers in the world. Changing here to smaller and lighter draught steamers the journey is continued 400 miles up to Ichang the end of all-the-year-steam navigation. This picturesque city of 50,000 inhabitants with its pyramid mountain and its horde of up-river junks will have been reached in ten days if all has been well. From here the best way to see the famous Gorges is to take a houseboat. Slowly being pulled up this wonderland of Nature one gets full chance to absorb the grandeur of this beautiful stretch. (The houseboat averages one mile an hour.) During the low water season (winter) a houseboat will cover this stretch from Ichang to Chungking about 450 miles in approximately a month depending upon the strength of the down river winds encountered. In the summer high water a steamer will make this trip in five days with several exciting times while passing the rapids. Arriving at Chungking sedan chairs are ordered for the 350 mile overland trip to the capital (Chengtu), coolies engaged, food boxes packed and off we go. The road is marked off in regular stages of about thirty miles each, and each night we put our bed up in a Chinese inn at the end of the stage, taking it down again the next morning. Every morning six o'clock finds the men starting, so we go on to the first village where the men stop for their rice before breakfast. At night the inn is reached, food prepared, all the loads counted to see that none have strayed off during the day and we are soon asleep and ready for the next day. Traveling so close to the country as one does on this kind of a trip, every day has its surprises and to one of an investigating mind thirty miles a day seems too fast to absorb all the new things seen. After ten days our journey comes to an end and we find ourselves welcoming the foreign house at the end of the line. The trip of 1,800 miles (Shanghai to Chengtu) has taken us six to eight weeks and we return richer in knowledge, with a better appreciation of the backward condition of interior China, marveling at the ingenuity shown at the earlier age and with sympathies broadened and outlook enlarged.

THUNDER AT SEA

Captain Ault, sailing master of the *Carnegie*, a non-magnetic ship under the direction of the Carnegie Department of Terrestrial Magnetism, has been investigating the audibility of thunder at sea, during the course of the voyage from Alaska to New Zealand from August 6 to November 2, 1915.

Lightning storms or displays were seen on twenty-two different occasions, but they were accompanied by thunder on only six occasions. In these six cases the distance of the nearest land was from fifty to six hundred miles. In all cases, however, where streak lightning was seen, thunder was also heard. The other cases were sheet lightning. It has been suggested that the frequent inaudibility of thunder at sea may be due to the fact that the sound of the thunder is drowned in the noises on shipboard during a storm. The *Carnegie*, however, observed lightning without thunder several times in calm weather. In one case in which several claps of thunder were heard, the successive intervals between flash and clap showed that the storm became inaudible when its distance exceeded five miles from the ship. The observations will be continued during the remainder of the present cruise of the *Carnegie*.

DEVELOPMENT OF COMMERCIAL DIRIGIBLES

REASONS WHY THE COMMERCIAL DIRIGIBLE IS A SERIOUS POSSIBILITY AND SOME OF THE WAYS IN WHICH IT CAN BE USED TO ADVANCE CIVILIZATION

BY RAYMOND B. PRICE

To ANYONE who has the opportunity to see what England is doing in the aëronautical field, it becomes clear that she intends to dominate the air just as she today dominates the sea. She is literally building aëroplanes by the thousand and dirigibles by the hundred. Her interest in dirigibles is not confined to any one type, but she is pursuing the problem with open mind and evidently intends to learn all that can be learned relating to the lighter than air mechanisms. Nowhere in France could I discover any great interest in the future of the dirigible and even those actually engaged in the industry saw for it only a moderate usefulness as a naval auxiliary with no promise whatever for commercial service. While England's vision of the usefulness of the dirigible is undoubtedly largely inspired by the vital importance of her naval protection and the established value of dirigibles for submarine hunting and coast and naval scouting in general, yet it seems likely that the impetus given to the development of the dirigible for these reasons will expand into a determined effort to make such craft so useful for commercial purposes as to help sustain the burden of supporting a considerable military dirigible establishment. One of our leading naval authorities has recently stated that if we in America possessed complete designs for a zeppelin and with every detail of information regarding its construction and assembling, it would still take two years before we could produce a serviceable zeppelin. Nor must we overlook the fact that it took Count Zeppelin ten years to find out most of the unsuspected dangers arising from imperfections in design and construction and operating dangers that thorough scientific foresight could not provide against nor even in some cases foresee. To the uninitiated it must have come as a great surprise to read of the difficulties and complications which Santos Dumont experienced in developing his early dirigibles. For what reason we do not know, it is only since the war started that zeppelins have been so shaped as to take advantage of the more recent knowledge relating to stream line shape, decreased resistance, and similar factors. Presumably the need for maximum speed even at some sacrifice of lifting power has been emphasized by military developments. Probably the zeppelin today stands forth as the world's foremost product involving the most recent scientific knowledge possessed by mankind. Within the past four months a British engineer officer about to attend a test of one of the latest British rigid dirigibles expressed the fear that she would break her back. It is thus evident that the development of such machines is yet absolutely in its infancy and we have no more right today to conclude that such craft will not in the course of a few years be of extreme commercial value than we have to say that no further progress will be made in engineering, chemistry, physics and education.

It is impossible, in a short paper, to enumerate the scientific problems involved in the construction of even a small dirigible, but it is safe to say that the most complete and up-to-date knowledge of the various sciences involved will be none too effective in meeting the problems of construction and operation, not only for military purposes, but perhaps to an even greater degree for successful commercial operation.

The commercial problem, however, has several elements to distinguish it from the military problem. Until there are aërodromes, repair shops and persons skilled in the handling and repair of dirigibles near almost every community where dirigibles are likely to be used, it is not to be expected that any considerable number of dirigibles could be in service. In spite of the great increase of meteorological knowledge, there will always perhaps be danger of such craft being swept from their courses by unexpected storms, and adequate places of refuge with trained assistants, day and night, must be provided before a general use of dirigibles can be successful. This involves, in addition, aërial charting of courses, development of comprehensive day and night signal systems and the necessary skill in using them. To a considerable extent, the aëroplane problem has corresponding needs and undoubtedly the development of the aëroplane will be sufficiently rapid to force provision of some such facilities for air navigation in the near future.

The expense of operation and maintenance is of minor importance for military purposes, but of paramount consideration for commerce. The bags of most of the balloons that have been used in the past have been constructed of silk, cotton, linen, or other fabric either oiled or coated with rubber. In all such cases, the permeability has been fairly high so that the loss of gas has been a serious item. This loss is generally increased with age owing to leakage resulting from deterioration and strains from mechanical handling. The commercial problem, therefore, must consider decreasing permeability and improving mechanical construction of the gas bag, as well as decreasing the cost of the gas. Until recently, when, either because of change of altitude or change of temperature, the gas expanded, it was necessary to relieve the pressure by releasing gas which was wasted. The modern zeppelin practice is to compress any surplus gas and keep it in containers so that it can be again used when needed. The construction of the zeppelin which provides an air space between the outer covering and the inner ballonets by minimizing changes of temperature, likewise reduces such losses. This intermediate air space, however, introduced a new danger because gas which had escaped from the ballonets became mixed with air and gradually assumed explosive proportions. Only recently has this danger been eliminated by ventilation of the intermediate air space. It has been suggested that this improvement has again permitted the use of anti-aircraft guns on top of zeppelins, although only a couple of years ago their use in that position was discontinued because of some danger not disclosed to the public.

It is obvious that every advance in concentration of strength and energy, every bit of progress in reducing weight without sacrifice of other qualities, brings nearer the day of the commercial dirigible. It has sometimes been reported that the passenger carrying zeppelins familiar to many Americans in Germany prior to the war were commercially profitable. It is doubtful, however, whether this would be correct without making allowance for government help of one kind or another. Perhaps enough has been said in this rather rambling outline to indicate that the commercial development of dirigibles must depend absolutely upon coöperation of a very far-reaching type. Those who are familiar with the work of the Automobile Chamber of Commerce and the Society of Automobile Engineers realize that the lesson they have taught the country is one which must be taught in general, not only for our commercial and industrial welfare, but for the very safety of the nation, and the coöperation which will be necessary to make quick progress in the commercial development of dirigibles should be far more comprehensive than anything that the automobile industry has yet experienced. Suppose, for example, that our national executives should decide that it is a matter of importance for the nation to have dirigibles developed rapidly so that their commercial and hence their military efficiency could be quickly made use of,

it would not seem impossible to organize a development committee, for want of a better name, somewhat along the following lines:

Members from:

(a) Government. Scientific experts from naval and military departments, Smithsonian Institution, Bureau of Standards, Post Office, Coast Survey, Coast Guard, Council of National Defense, National Research Committee, government laboratory recommended by Naval Consulting Board, Weather Bureau.

(b) Scientific organizations. Societies and individuals, colleges and technical schools, geographical and exploration societies, associations of doctors and lawyers.

(c) Industries. Metal manufacturers, engineering firms, textile and wood-working concerns, rubber and other industries based upon colloids, scientific instrument makers, chemical industries, motor manufacturers.

(d) Commercial bodies. Chamber of Commerce of the United States, merchants' associations, distributors of light expensive merchandise, real estate boards.

(e) Transportation interests.

(f) Sporting and publicity bodies. Automobile and aëro clubs, hunting and traveling associations. Navy League, National Security League, and patriotic organizations, Advertising Clubs of the World.

(a) The importance of government initiative in this matter cannot be overestimated. While every other important nation in the world is concentrating all of its resources and forces, without exception, under government leadership, our government on the contrary tends to evade its responsibilities. This is a very serious matter, worthy of the careful study of every thinking American, because it is today an open question whether forty-eight loosely united, almost independent, states, without strong federal government leadership, can compete successfully with other industrial nations, compact and coördinated. It seems especially important by every means possible to urge our government to show leadership especially in those departments where the necessary ability and organization already exist. Therefore, a small committee representing the best brains and optimism of our naval, military, post office and other government departments would be not only a tremendous help, but the psychological effect on the other groups would be decisive. Dirigibles might readily connect with steamers well out at sea and take mail to or from inland cities, thus saving not hours, but days in communicating with Europe and other continents. Many other federal functions are involved.

(b) The importance of refining everything from motors to fabrics down to small fractions of 1 per cent, involves the most comprehensive use of all of our scientific brains and resources. As many legal questions will arise as air navigation increases, even the lawyers can do their part. It has been stated that airships have caused remarkable cures of some nervous troubles. With berths, hot meals, electric light and electric heating, already possessed by zeppelins it is not beyond the limits of possibility to consider aërial sanitaria. The whole effect of air travel upon man must be studied.

(c) The astonishing increase of knowledge of the properties of alloys in the past few years leads us to expect still more important discoveries in this field in the near future. The combined resources of our steel and other metal plants, with their highly efficient chemical and physical laboratories, the coöperation of engineering firms, the more scientific investigation of textile methods and products, the better methods of testing and evaluating both wood and metal constructions, all lead to expectation of great progress in those directions. It is known that materials exist which are one hundred times less permeable to hydrogen gas than is rubber as now used, so great possibilities lie ahead through coöperation of the experts and applying the resources of the colloidal industries.

(d) The Chamber of Commerce of the United States, with its national affiliations and interests, could well number among

its activities the furthering of dirigible development. Everything which tends to facilitate communication between localities tends to the advancement of the nation. There are large quantities of comparatively light but expensive merchandise which perhaps even today would stand the expense of aërial transportation. The obtaining of ground for hangars and repair plants and for flying fields will test the abilities and enthusiasms of our real estate boards, as well as our local chambers of commerce and other associations.

(e) As feeders for railways in sparsely settled communities or in locations where railroad building is extremely difficult or expensive, as means for carrying mails and light merchandise in similar country, even as competitor for the automobile where roads are scarce or forests and other obstructions control, in many ways it is conceivable that the dirigible could be placed at the service of mankind.

(f) We have passed from the bicycle to the automobile and now are passing from the automobile to the aëroplane, and from the aëroplane to the dirigible is but a short step. This does not mean that any of these mechanisms are losing in usefulness, but on the contrary, each is filling a larger and clearer field of its own. Exploration, traveling for pleasure, even hunting can be carried on by air with marked advantage.

It may seem to some that the end is not worth the means, that the aëroplane will do all that the dirigible can and that the difficulties in the way of developing the dirigible commercially do not warrant the effort. On the other hand, the dirigible has inherent advantages not possessed by the aëroplane. It is quite conceivable that the future will witness a combination of the advantages of dirigible and aëroplane in some compromise craft which will depend partly upon the aëroplane wing and partly upon the gas bag. Such a craft might have less speed and consequently be easier to land. It would have greater bulk and thus be an easier prey to wind and storm than the aëroplane, but it is evident that in one type of craft neither all of the advantages nor all of the disadvantages can be combined. Already the dirigible makes valuable use of planes and the little British "blimp" instead of a car has beneath its gas bag an aëroplane fusilage, so that it can slide along the ground somewhat as an aëroplane can. It is said to cost France today $5,000 to train every aviator. This could scarcely be considered a commercial proposition, though, of course, this figure is the result of war hazards, war pressure and the necessity for war speeds and constructions. It is necessary to keep a clear vision between the exigencies of war and commerce, although each is closely related to the other and progress in one must result from progress in the other.

It is entirely conceivable that our cities of the future will be built with flat roofs, all of a level, with the streets covered over with glass so that either aëroplanes or dirigibles could land on the roofs, and those residents of suburbs a hundred miles distant could land from their air machines directly over their offices in a minimum of time. This might involve the elimination of chimneys by means of forced draught or preferably by the production of power in central plants or at the coal mines and the distribution of heat, light and power electrically, which many of our best experts in this field have already promised us for the comparatively near future.

Whether or not the dirigible becomes of commercial value, probably depends more upon the United States than any other country. Whether this achievement is recorded to our credit or not may depend upon the national imagination, optimism and determination. The military and naval development of the dirigible is inevitable, but it may require the vision, courage, bigmindedness and generous coöperation of all of the agencies which have been enumerated and many others to achieve the real possibilities of the dirigible, at any rate, within the lifetime of most of us. Let us hope that the Council of National Defense may see the vision and be given the power to be the moving factor in realizing this great benefit to mankind.

THE INTERNAL SECRETIONS

CHEMICAL FACTORS IN THE REGULATION OF THE ORGANISM —AN EXPANDING DEPARTMENT OF PRESENT-DAY BIOLOGY

BY PERCY G. STILES

One need not be a profound student of science to appreciate that the coördination of activities is a most striking fact of animal life. What happens in one place is adapted to what is occurring at another. It may fairly be claimed that each part acts more distinctly for the good of the whole than for its own advantage. Clearly, this could not be the case if there were not some mode of transmitting influences from organ to organ.

When one considers the possible means of such transmission the nervous system is at once suggested. This wonderful structure is so fashioned that, conceivably, any part of the body may definitely affect any other. It is in this respect like a telephone exchange which affords to each subscriber the opportunity to communicate with any other. The nervous system has long been looked upon as the essential instrument of coördination. A second possibility has lately become unexpectedly prominent. It is the transmission of chemically active products through the medium of the circulation.

Such products of the tissues are usually called internal secretions. A compound added to the blood by one organ will, within a minute, be quite uniformly diffused over the whole body. There is no way to limit its distribution and bring it all to bear upon a restricted portion of the system. In this respect the interchange of influences by means of internal secretions lack the refinement and precision which characterize the nervous correlation. We have to do with a set of drugs which, like those administered by the physician, must be offered to all the tissues—to those which seem indifferent as well as to those which are evidently responsive.

The internal secretions have proved to be more numerous and more important than anyone would have predicted fifty years ago. The subject will doubtless occupy a larger and larger place in future expositions of physiology. A brief summary of the matter as it now appears may be attempted. The part played by these chemical messengers can conveniently be stated under three headings.

I. *Internal Secretions and Growth.* Normal development cannot be accomplished unless the blood receives certain contributions from several small organs. One of these is the thyroid in the neck. If this fails to play its part the growth of the child is arrested. Nor is the result a simple dwarfing of stature; the proportions and features are grotesque and the mental retardation parallels the physical. The proof that this condition (cretinism) depends on thyroid failure is satisfactory: the mingling of dried thyroid substance from animals with the food of the cretin gives a marvelous impulse to its development. The treatment, fully continued, may nearly counteract the defect.

Another organ, which radiates a well marked influence upon growth, is the pituitary body, an inconspicuous appendage upon the under surface of the brain. Its action may be perverted by disease with the result that there is overgrowth, tending toward the gigantic. In other cases of pituitary disorder there may be malformation of the bones. The effect on the configuration of the face may be startlingly uncouth. Even in adult life these changes may set in.

The thymus, a mass of tissue high up in the chest, is believed to regulate growth in some obscure fashion. Much more distinct are the relations which exist

between the reproductive organs and development. The dependence of a symmetrical type upon the normality of these organs is familar. It should remind us that any group of cells may have more than one function; in this case the dispensing of internal secretions reacting upon the individual goes along with the preparation of the germs of the coming generation.

II. *Internal Secretions and Maintenance.* The thyroid and the pituitary body which so profoundly affect the course of growth continue to exert a regulation upon the processes of mature life. Loss of the thyroid by an adult leads to a serious depression of health with physical signs recalling cretinism. Loss of the pituitary—if we may judge from the case of the lower animals—cannot be survived.

At least two other organs make contributions to the blood which cannot be spared for any length of time, the pancreas and the adrenal bodies. The pancreas was long known to elaborate an important digestive juice. But it is like the organs of reproduction in that it does not merely separate something from the blood but adds something to it. Removal of the pancreas without doubt impairs the digestive capacity but this result is overshadowed by another: all the tissues lose the power to oxidize, and so to profit by, their chief fuel which is sugar. This loss is the central fact in diabetes. When developed to its limit the power to use fat is also abolished and the problem of nutrition becomes hopeless.

At the back of the abdominal cavity, above the kidneys, are the paired structures known as the adrenal bodies. Insignificant as they appear they are vital organs, the removal of which is followed swiftly by prostration and death. Something must go out from them which gives tone and efficiency to more than one system. When the adrenals are gradually wasted by disease the failure of strength corresponds with the degree of their destruction. Their extracts do not successfully compensate for the lack of living cells; the body seems to need a slow, uniform delivery of this internal secretion and periodic dosing does not prove equivalent to the natural condition.

III. *Internal Secretions at Particular Times.* So far we have spoken as though internal secretions were set free slowly and steadily, having their effects throughout long periods. It remains possible that they may be discharged to the blood somewhat suddenly under peculiar circumstances. We have the best of evidence that the adrenals can thus be thrown into a temporary activity far beyond their ordinary performance. The particular occasion for this is one of stress and excitement. It has been clearly proved that as such times the chief product of the adrenal cells (adrenin) is increased in the blood. It has also been proved that this internal secretion confers upon an individual the utmost command of his physical resources. There is ground for the belief that the thyroid as well as the adrenal tissue has special awakenings to accelerated production.

We began by stating that one organ of the body may influence another either by nerve-impulses or by secretions carried in the blood. These two types of action admit of some combination as will now be obvious. The temporary arousing of the adrenals in emergencies is certainly due to a stimulation effected through the nervous system. The thyroid is probably under a similar nervous government. Hence, in these two cases if not in others, a reaction that is first mediated by the nervous system may be completed under the influence of internal secretions.

The medical doctrines of the Greeks centered upon the theory of the Four Humors, according to which health depended on the maintenance of right proportions among four essential ingredients of the body-fluids. It is interesting to observe that we are once more giving place to views very suggestive of the old. We believe not in four but in a considerable number of active substances which must be rightly balanced. Abnormal conditions may arise either from deficiency or from excess on the part of any one of these.

It is not long since physicians assigned their patients to groups according to "temperament," the lymphatic, the sanguine, and so on. The scientific equivalents of these designations seem to be connected with the organs of internal secretion. The diagnostician can now recognize in a peculiar type, the evidence of an over-active thyroid, in another the signs of pituitary excess. When one looks at the pictures of men suffering from serious diseases of these organs one is constantly impelled to say, "Why I have seen people who looked like that!" It is fair to suppose that for every bad case of this class there must be many mild ones. Most of these will not be recognized as pathological. As individuals can be found to suggest all types of insanity while yet keeping within the province of the sane so we can see hints of departure from the ideal balance of the internal secretions in those who are still effective members of society.

THE ICONOCLASM OF FACT

Man's aptitude to form rash conclusions from insufficient data and then use these conclusions as facts upon which to base subsequent statements and even philosophies is nowhere better exemplified than in the realm of geology and astronomy. Observing that from volcanoes red hot liquid rock came from within the bowels of the earth it was concluded that all of the earth's interior was molten rock. Secondly, it was argued, since the earth's surface was cold and the interior hot the earth must represent a star cooling from a gaseous through a liquid state. When sufficiently cool a crust of solid rock would form. Since then, it was argued, only a thin crust separated the earth's surface from the exceedingly hot interior during the early ages of earth history, the climate of this time must have been quite warm from the great amount of heat received from the interior. As the crust became thicker and thicker, less and less heat came from this source and consequently this uniformly warm, humid climate changed gradually during the geologic ages to a diversified one, whose zonal arrangement was finally due to the heat received from the sun, and it was only in late geologic time, in fact, just before the present, that the heat, received from the interior of the earth, had decreased sufficiently to permit the occurrence of frigid zones and glaciers.

During the last ten to twenty years this theory of gradual refrigeration has been attacked both by astronomers and geologists. One of the strongest weapons of the latter has been the discovery of evidences of glaciers practically throughout the entire geologic column. Such characteristic glacial ear-marks as till, striated pebbles, polished and grooved rock-floor over which the ice had moved, are as common far back in the earth's history as during the last great ice age in whose closing stages we are now living. A glacial period, greater than that which lately covered much of North America and Europe, scoured the lands around the Indian Ocean at the close of the Paleozoic Era, twenty million years or more ago. Just previous to the Paleozoic, before the incoming of the earliest definitely known fauna, occurred another great ice age, of whose wide area of distribution there is accumulating proof. Glacial deposits of this age are known from Europe, Asia, Africa and Australia. Finally till and striated pebbles have been found across northern Ontario for a distance of 800 miles and from latitude 46° to 50° in rocks of Lower Huronian age, which are next to the oldest rock formation known. There is evidence of glacial deposits of similar age in Scotland and possibly in China.

With this demonstration of the presence of glaciers upon the earth at practically the very beginning of geologic time the earlier theory of the very gradual refrigeration of the world's climate is proved untenable. And that this is another of man's many hypotheses based on insufficient data is further attested by the complete evidence of the alteration of glacial climates with tropical or semi-tropical climates prevailing over almost the entire earth. H. W. S.

EVOLUTION OF SERVICE

HOW THE COMPULSORY SERVICE THAT STIMULATED LIFE AND EVOLUTIONARY PROGRESS IS BECOMING VOLUNTARY— AN ANALOGY FOR THE OPTIMIST

BY H. W. SHIMER

SERVICE is an essential to life upon this earth. Should no help be given to others, all life would cease to exist within a single generation. This service is surely compulsory in the vast majority of plants and animals, but it becomes more and more a voluntary helpfulness in the higher forms of animal life. In the following article the various kinds of service will first be defined and then their influence in the evolution of earth's life from the earliest times to the present noted.

When one animal eats another the latter performs a service for the former though it is surely a compulsory one. The total amount of suffering is, however, infinitely less than is the compulsory service of the sweat-shop worker who knows that he must slave hopelessly on until death comes as a welcome relief. To the animal all is joy until the quick sharp pang of death. J. G. Holland expresses in his "Bitter-Sweet" the universality of this form of compulsory service: he says,

"Life evermore is fed by death,
In earth and sea and sky,
And, that a rose may breathe its breath,
Something must die.

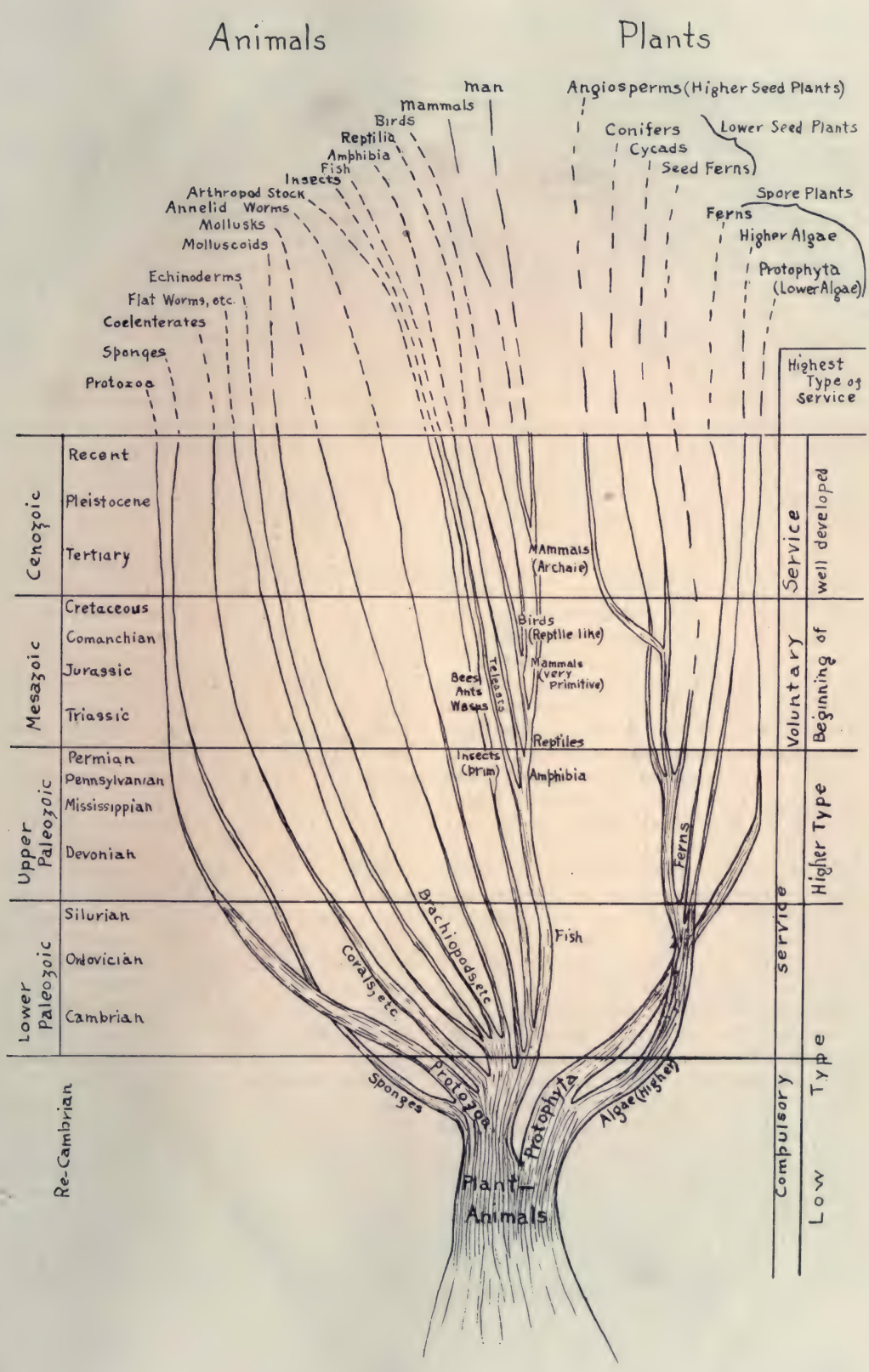
"The milk-haired heifer's life must pass
That it may fill your own,
As passed the sweet life from the grass
She fed upon."

It is to this type of service that is due all animal life and all higher forms of vegetation. That it has existed upon the earth from the early times of earth history to the present is proven not only by the fact that all animals at present live upon other organisms but that animals with teeth, claws, tentacles and other food-procuring devices occur fossil in the rocks of all those ages.

Another type of compulsory service, especially common in plants, is the yielding of the parent's life in the production of young. We see this in the majority of herbs and grains,—the radish, cabbage, wheat and oats all must give their life to produce seeds. Though this manner of producing offspring is not so characteristic of animals, yet it occurs among insects, corals, and many other groups. This type of service was likewise present from the earliest periods of earth history to the present.

A most important type of compulsory service from an evolutionary point of view is the storage of food for the developing young. This is seen typically in the yolk mass surrounding the embryo in the bird's egg and the starch nutriment enclosing the very young wheat stalk or oak tree.

The definition of voluntary service will here be somewhat broadened and be made to include the variability among individuals of the same species, or variety, in the amount and kind of labor they expend upon their young. Some birds, for example, though trembling with fright, will continue to sit upon and protect their eggs even when threatened with death; while other individuals of the same species desert their eggs or young upon the least approach of danger. Some sun-fish will fight courageously to protect their rude nests, others are very timid. In the solitary wasps, typified by ammophila, Mr. and Mrs. Peckham have shown that individuals of the same species differ


Animals
Plants
man
Mammals
Birds
Reptilia
Amphibia
Fish
Insects
Arthropod Stock
Annelid Worms
Mollusks
Molluscoids
Echinoderms
Flat Worms, etc.
Coelenterates
Sponges
Protozoa
Angiosperms (Higher Seed Plants)
Conifers
Cycads
Seed Ferns
Lower Seed Plants
Spore Plants
Ferns
Higher Algae
Protophyta (Lower Algae)
Highest Type of Service
Cenozoic
Recent
Pleistocene
Tertiary
Mesozoic
Cretaceous
Comanchian
Jurassic
Triassic
Upper Paleozoic
Permian
Pennsylvanian
Mississippian
Devonian
Lower Paleozoic
Silurian
Ordovician
Cambrian
Pre-Cambrian
Mammals (Archaic)
Birds (Reptile like)
Mammals (very primitive)
Bees
Ants
Wasps
Teleosts
Reptiles
Insects (prim)
Amphibia
Ferns
Fish
Brachiopods etc.
Corals etc.
Sponges
Protozoa
Protophyta
Algae (higher)
Plant—Animals
Service
well developed
Voluntary
Beginning of
Higher Type
Compulsory
Low Type

greatly in the amount of food they furnish their young. Some are good providers, others poor. Some also are exact and precise in all their movements, others are very negligent and disorderly, leaving their offspring less effectively protected in numerous ways. This difference in the instinct of helpfulness to offspring between individuals of the same species is here called voluntary service.

As we take a bird's-eye view of the history of the earth we see that compulsory service has always been present but that it increases in effectiveness from ancient times to modern. We note too that voluntary service first appeared, minute both in kind and amount, during the medieval period of earth history and has rapidly increased in effectiveness to the present. Voluntary service occurs only in those animal groups which can respond to a high type of compulsory service. It is this additional service to offspring which enables their possessors to succeed so well in the universal competition,—this most efficient goad to evolution.

As we see from the chart the plants in existence during the pre-Cambrian and lower Paleozoic are those that multiply by spores—special cells developed by the parent to carry on the race. These spores, compared to the seeds of higher plants, stand but little chance of developing into adult plants. A few of the animals present during these early times likewise reproduced their kind by means of spores but most of the groups produced two kinds of cells, large ones called female and small ones named male; the union of two of these different kinds was necessary to produce a germ which could develop into an adult form like the parent. These reproductive elements, the male and female cells, were thrown by the parents into the water where if union happened to occur a new individual resulted, otherwise they died.

By mid and upper Paleozoic, plants and animals had become so evolved that they could furnish nutriment for the developing embryo. Among plants small seeds were present in the seed-ferns, primitive cycads and conifers. Among animals a capsule, enclosing yolk, surrounded the embryo in all the dominant classes from the mollusk to the fish, amphibian and reptile. This high type of compulsory service was already present during the lower Paleozoic, among the mollusks and arthropods, but here the amount of yolk stored was small. The surrounding tough capsule protected the developing embryo from many of its enemies while the enclosed yolk ensured sufficient food for considerable growth, so that upon leaving the capsule it would have a better chance for survival to maturity.

If we may judge by the most nearly related living forms, there must likewise have been present during the entire Paleozoic a rudimentary kind of instinct, with but a minimum amount of free choice and hence of voluntary service. Even the insects, first appearing in the upper Paleozoic and rapidly becoming so numerous in the vast coal-swamps of that time, all belonged to the lower orders with a very low degree of instinct.

With the evolution in the Mesozoic Era of the higher seed-plants, insects and fish, and of the most primitive birds and mammals, a higher type of compulsory service was initiated and a distinct beginning in voluntary service made. The higher seed-plants, typified by the oak and hickory, furnished a larger amount of embryonic nutriment and better seed protection than did the primitive seed plants of the upper Paleozoic; the nutriment was surrounded by a protecting capsule. The development of bees, ants and wasps with the mid-Mesozoic was most probably accompanied with a beginning of that wonderfully evolved instinct and of some voluntary service to their young, as well as to the members of the community, which characterize their modern representatives. The incoming at the same time of the highest order of fishes, the Teleostei, may likewise have been accompanied in some individuals, as it is in many of their living descendants, by a certain amount of voluntary service.

Some of the Mesozoic mammals, allied to the existing monotremes, probably like these laid eggs, hatched them as birds

now do and then suckled the young; while others, more nearly related to the kangaroos and insectivores were, in all probability like their modern representatives, forced to protect and nourish the embryo within the body until well developed, and after birth to continue this care by fighting off enemies and nursing the young. While all the service before birth, and much after it, was compulsory there still remained a distinct amount of voluntary service both in hatching the eggs and in feeding and protecting the offspring.

During the Cenozoic appeared the highest forms of service, both compulsory and voluntary, yet developed on the earth. The production of conspicuous flowers, of nectar and other devices for the perpetuation of species of plants is a form of compulsory service originating mostly during the Cenozoic, though undoubtedly some of these devices received their inception in the Mesozoic.

The development in the Cenozoic of the living groups of birds was accompanied, if it did not originate in the Mesozoic, with the hatching instinct. A considerable amount of this instinct is, however, voluntary service, since it differs so greatly among individuals of the same species or variety. After the young are hatched the parents are doubtless compelled by instinct to feed and protect them, but here again much of the service is without doubt voluntary. (Since the birds of the Mesozoic were reptile-like in the sharp teeth, claws upon the wings and long vertebrated tail possessed by most individuals they may also have been reptile-like in their failure to personally hatch their eggs and feed and protect the young.)

The appearance of carnivore, rodent and hoofed mammals in the lower part of the Cenozoic initiated a much higher type of voluntary service. These mammals, to judge by their nearest living relatives, were compelled to serve their young before birth by interuterine nourishment and after birth through the secretion of milk. They also protected their young as well as their mates, and procured them solid food. They were, doubtless, impelled to these latter acts by instinct but a considerable amount of voluntary service was present.

In the upper part of the Cenozoic appeared man and with him began the development of the highest type of voluntary service yet evolved upon this earth. Slowly, extremely slowly, it advanced at first and was for long doubtless limited to the family; but gradually it was extended to other members of the clan, nation, language and finally even to the barbarian, heathen or gentile, and even to lower animals and to plants. Man is, however, still under the law of compulsory service. The unborn young must still be given interuterine nourishment and the young child food and care, while public opinion and man-made laws force the laggard to duties which he is not yet sufficiently evolved to perform voluntarily.

We thus see that the development of life upon this earth was due to service, that without such service no higher forms of life could have evolved. Animals can live only through the death of other animals or of plants. Both animals and plants are compelled to give of their strength, or often life itself, in the production of young. As animals and plants became more highly evolved they developed a higher type of service, that of furnishing more nourishment and better protection to their offspring. Very gradually, side by side with the higher kinds of compulsory service, there was evolved a voluntary service; minute in kind and amount at first, it has finally come in the nobler members of mankind to dwarf the former by comparison into insignificance. Pre-Paleozoic time and the long Paleozoic Era stand for low types of compulsory service; the Mesozoic for higher kinds of compulsory service with a definite beginning of voluntary service; while during the Cenozoic this latter type increased in amount until at present in man it far over-shadows the service of compulsion.

Evolution as we see it upon this earth has thus occurred through each successively higher group taking more and more from others, especially from parents, and giving more and more in return, especially

to offspring; the service rendered is passed on, not returned. When, however, a plant or animal group takes more and more from others without giving additional service in return we have parasitism, and parasites are not now, nor were they in the distant past, in evolving lines. Parasites, whether plant, beast or human, are degenerate; the individuals become weaker and weaker and finally the line ends in death. Those who give more than they receive are thus in the advance line of evolution; they blaze the way for the others to follow. It has always been so. The advanced lines of both plants and animals must always have given a certain amount of service, even though minute, above that which they had received; otherwise these higher types of service could not have come into existence. The vast majority of plants and animals are stand-patters; they give what they receive because they must.

The trend of evolution has thus been from compulsory service to voluntary, from an enforced aid to others, to help given because of love for others.

Since the path of the past shows us the road of the future we may feel assured that future ages will see all humanity developed into the universal sympathy and loving service so characteristic of the highest types of today. Optimists have thus a solid basis for their philosophy. It is the pessimist who sees but a portion of the whole; he sees but a part of a pendulum swing, not the definite advance after the forward and backward motion.

FOSSIL BACTERIA DISCOVERED

Marvelous as were the discoveries of such pre-historic monsters as the Mammoth, the Mastodon, and the Stegosaurus, they are now eclipsed by recent investigations which show the most minute microbes and bacteria in fossil form. The ancestors of our modern infectious disease germs and microbes have been found in fossils of the earliest life on the earth. Fossil bacteria have been discovered in very ancient limestones collected by Dr. Charles D. Walcott, secretary of the Smithsonian Institution, in Gallatin County, Montana. For some time Dr. Walcott has believed that these bacteria existed, and mention of the fact was made before the Botanical Society of Washington on April 6, 1915, when attention was called to their existence in association with fossil algal deposits of the Newland limestone. The belief that bacteria were the most important factor in the deposition of these ancient limestones was also mentioned by Dr. Walcott in a preliminary publication of the Smithsonian Institution. At that time, however, no definite bacteria had been discovered, but in thin sections of limestone from the collections made in 1914 the microscope now shows these very minute forms of life, some twenty to thirty million of years old. The bacteria were discovered in three sections cut from an algal form included under the generic name Gallatinia, named after the great American explorer Gallatin. The bacteria consists of individual cells and apparent chains of cells which correspond in their physical appearance with the cells of Micrococci, a form of bacteria of today. The world has believed that bacteria were modern forms of life but now we are made to realize that they existed in the dawn of world history, many million years ago.—*Scientific American.*

"BE A SPORT"

This expression is always used to encourage experience upon the physical and passional side, the "past good" in man. The use of it as a spur to see the demonstration of a new machine, to attend a lecture, or listen to a prayer, would create laughter. Yet just as finding experiences for his mental and spiritual natures spells man's advance today, so during the early history of the race the coarser spurs of passion, of physical gratification, were necessary.

What in these older ages was a present good has today become a detriment, a hindrance to man's present evolution.

H. W. S.

EVOLUTION THROUGH CONTRASTS

THE principal effect of the cold morning sponge bath is its stimulation of all the body organs. After it man is wide-awake mentally as well as physically. He has received energy and poise which will not be followed by any bad after-effects. This is caused by the contrast between the warmth of the body and the cold water. Similarly, we in the temperate zone work better mentally in the cooler months of fall and spring, when the contrast between the cold of out-of-doors and the warm rooms stimulate us out of our natural slothfulness. If, however, the contrast is too great the effect is detrimental.

It has been shown that those areas of this globe have the most energetic, the most highly evolved peoples which are swept by frequent cyclonic storms. The contrast between the lower temperature, higher humidity and lessened atmospheric pressure during the storm and the opposite during clear weather is given as the principal cause. The difference between the lower temperature of night and the higher of day has a similar stimulating effect.

The contrast between winter and summer, cold and warmth, humid and dry atmospheres, low and high pressures, does not affect man alone but the entire organic kingdom. Its effects upon all plants and lower animals is greater than upon man himself, that is his body, for man partially creates his own environment and thus tends to obliterate the effect of some of nature's spurs. Mind, the central nervous system, not only of man but of all animals, is more sensitive and consequently more profoundly influenced by these causes than the body, and is likewise strongly affected by the passions.

Day and night, bringing a greater or less increase in the feeling of safety and fear, causes an exercise of the nervous centers, which exercise tends to their enlargement. The frequent recurrence of hunger for food and its satiation, the joy in the pursuit of food and the fear of capture, are also common to all animals, while in the higher forms anger at having their food snatched away by another or their home or loved ones attacked, leads to further stimulation of these centers, while the lengthening of memory in man increases the strength of love and frequently changes anger into hatred.

With the rapid increase in the depth and breadth of love in the higher representatives of mankind, the necessity for hatred, anger, fear, and the other lower passions has disappeared. The love of the most highly evolved as well as the least, of learning, etc., here furnishes more energy than all the passions combined; it is, too, a source of energy which does not weaken man. The mere mental entertaining of the lower passions weakens his body, as anyone can easily see, especially after the body is somewhat weakened by disease; while thoughts of affection strengthen it.

Much of mankind still needs these contrasts of fear and safety, anger, joy, etc., for the development of sufficient energy to continue evolving, and could rightly no more see the desirability of anyone overcoming the passions than the horse-shoe crab the future disappearance of the mud and slime in which he takes such pleasure and from which he gets much of his food for growth and development.

In the evolution of life as we know it upon this globe, the chief external factor, aside from the sun in its rôle of heat and food provider, has been the spurs towards energy through nature's contrasts. During the earlier geologic ages, that is, before the appearance upon the earth of the higher forms of life, these spurs were mainly those which affect the body, such as hunger and its gratification, heat and

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cold, light and darkness; though very early did the central nervous system add its spur in the development of energy through the feelings of fear and safety. In later geologic times, with the development of the higher forms of mollusks and arthropods, and especially with the incoming of the vertebrates, the production of this energy has been principally through the central nervous system. Anger and love, the latter rapidly increasing in the higher members of mankind, are here the principal spurs; and the lower forms of energy-making are still effective. It is the higher forms which are most efficient.

During the evolution of life, energy and evolution are thus synonymous terms, with mental energy a later and higher development than physical energy, for the amount of energy, active or in reserve, is a standard of evolution; and this energy through the ages has been derived from successively higher and higher sources. The purely physical stimuli furnished by the natural surroundings of organic life have yielded in effectiveness to the gradual growing stimuli resident in life itself, in its emotions of anger and love, and later in the push of the intellect and spirit. H. W. S.

DISCONTINUANCE OF SCIENCE CONSPECTUS

IT IS with much regret that we announce the discontinuance of SCIENCE CONSPECTUS, with this issue. The expense and effort required to publish a magazine with limited circulation and with no resources from advertising, are too great to warrant its continuance.

Although we have not been able to fully carry out our aim in founding this magazine, it has been possible to find some men of scientific attainments who have the happy faculty of making their subjects clear to lay readers, many of whom are scientists themselves in another field of endeavor, and to this extent we have fulfilled our mission.

That there is a field for such a publication covering a broader scope, perhaps, is shown by the great interest our readers have taken in SCIENCE CONSPECTUS. It is hoped that this field will sometime be covered by an ably conducted publication.

The editors are indebted to the friends who have contributed to this magazine, and also to its readers whose appreciation and encouragement have been frequently and generously expressed.

PHOTOGRAPHY OF HIGH VELOCITIES

HOW BULLETS TRAVELING 92,200 FEET A SECOND HAVE BEEN PHOTOGRAPHED— HOW HIGH SPEED PHOTOGRAPHY MAY BE USED IN RESEARCH

BY W. A. HYDE

ONE of Christian Huygens' brilliant conceptions was that a sound wave might be considered as made up of a number of elementary waves, each centered on the wave front of an instant before, as in Fig. 1. Here O is the center of disturbance and after a given interval of time the spherical wave front has reached AB. It was Huygens' theory that each point on this wave front, as a, b, c, etc., was the source of small elementary waves; by taking them sufficiently close together their bounding surface $A'B'$, called the "envelope," would be a circle slightly farther removed from O than AB. In this way the wave is assumed to travel through the air.

A striking confirmation of this is shown in Fig. 2, which is a photograph of a bullet with its attendant air waves passing through a pipe, through the sides of which slots have been cut. The photograph was taken at the Militärtechnische Akademie at Charlottenburg, under the direction of Dr. Carl Cranz, and was handed to the writer during a visit there in 1914. The bullet is traveling about 2,700 feet per second, greatly in excess of that of sound and, therefore, forms a wave of compression in the air continuously, as shown. This wave is constrained by the wall of the pipe but emerges from the apertures in the form of small waves whose centers are at these apertures. It is apparent that the envelope of these wavelets is the head wave of the bullet; analysis and synthesis are seldom so plainly combined.

An elementary diagram will make this clear (see Fig. 3). Suppose AB to be a thin rod moving to the left with a velocity V, greater than that of sound, S, in the medium. At any instant previous, A was at A', say. At that instant it was the source of a disturbance which caused a wave of compression to travel outward, till at the end of this given time interval the sound wave had traveled to C' with a velocity S, characteristic of the medium. In air this velocity is 1,100 feet per second.

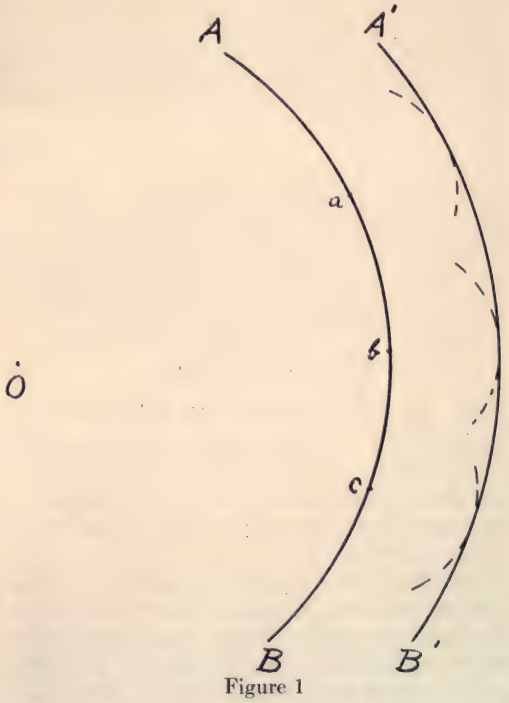

Figure 1

An instant previous to this the end A was at A'', say, and during the time of passage of the rod from A'' to A sound had traveled a distance $A''C''$. The wave front has then assumed the direction $AC'C''$. With uniform velocity of the rod in a homogeneous medium it will be seen from the geometry of the figure that $AC'C''$ is a

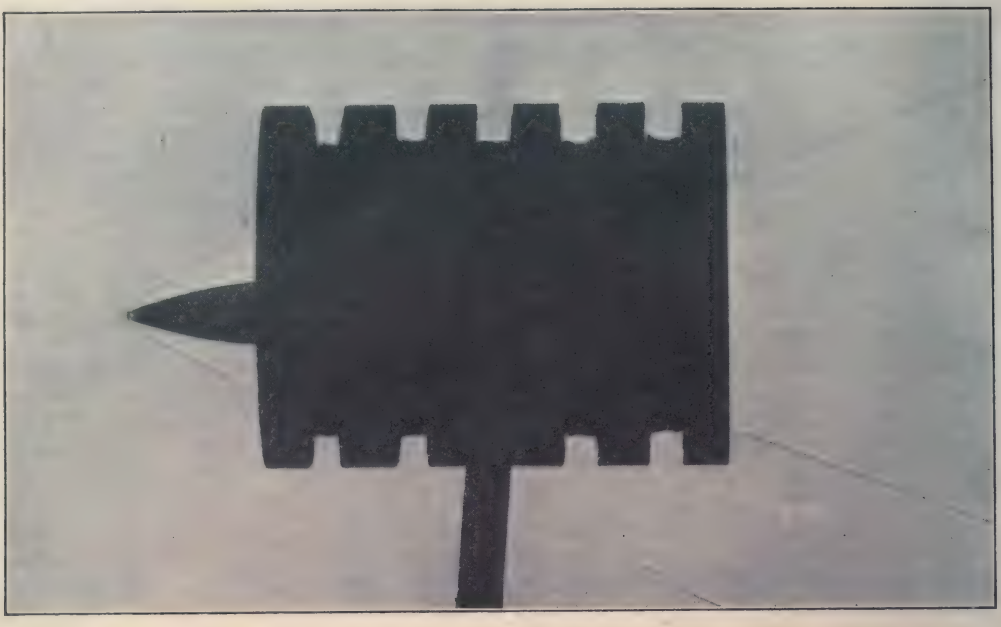

Figure 2

straight line. This illustration does not apply where the velocity of the rod—or disturbance—is less that the velocity of sound in the medium, for in that case the disturbance travels away faster than it is made. From the figure it is seen that the sine of the half angle $\alpha = \frac{S}{V}$, so that the velocity can be computed as $V = \frac{S}{\sin \alpha}$. In practice it is found that the head and tail waves are not parallel; the angle α is determined by a line lying between them.

Methods of obtaining this and similar photographs may be added here, partly to make the article complete and partly to serve as a suggestion for future research and application. Fig. 4 shows the apparatus for one method. *M* is a concave spherical mirror, *S* a spark gap, *C* a camera and *E* a sharp edge, all enclosed in a box or light tight room. The bullet passes through a spark gap *G*, enclosed, discharging a condenser circuit at the time, without, however, touching either terminal. The circuit, shown in Fig. 5, is arranged to give a definite time lag between the passage through *G* and the setting off of the photographing spark *S*. There are three oscillatory circuits, charged in parallel by a static machine at *G*. *L* is a variable inductance and *R* is a very high resistance, preferable a tube of slightly salted water. *R* permits

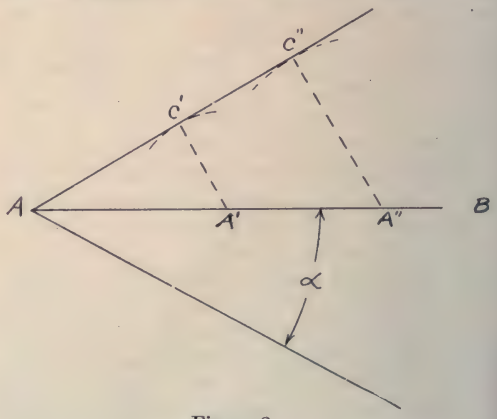

Figure 3

the charging up of C_3 and prevents its discharge except at the proper time through *S*. The circuits are all made up of short thick copper wire. The period of *I* is shorter than that of *II* and by strong

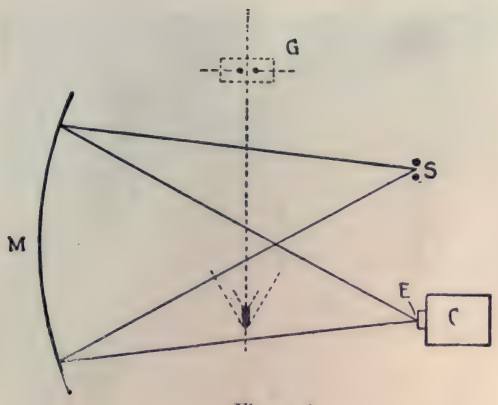

Figure 4

damping I can be made to discharge before II begins. There results a high difference of potential between m and n and the voltage across S rises. With a proper length of gap S circuit III will discharge when II has made one half oscillation, which can be varied at L. In practice a "time lag" of 1/2000 second has been found satisfactory.

Another method, not so precise as to locating the bullet at the time of photographing, is shown in Fig. 6. C_1 is a large and C_2 a small condenser, S the photographing spark gap, R a high resistance, T a tube connected to a ring through which the bullet passes, F a gas flame and D a disk with a hole in it. As the bullet passes through the ring a wave traverses the tube and blows the ionized gas through the hole in the disk to the other terminal, thus "triggering" off the spark at S. The small condenser C_2 is discharged but the resistance R prevents the discharge of C_1 until the difference of potential at S is great enough to break

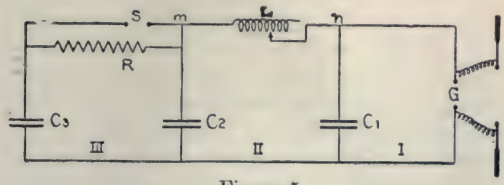

Figure 5

down the gap. The camera used in the above experiments was fitted with a lens working at $F/3.5$ and the mirror was about 12″ in diameter. The results are singularly beautiful as may be seen from Fig. 7, which is a photograph of a German bullet at about 2,700 feet per second. A faint idea of the variation in intensity of the wave front may be obtained by the way the wave shades off. It is rather surprising, too, that such a well defined tail wave is found. The "wake," at the rear, is not smoke, since this method of photography shows the variations in the refractive index of the air. Besides, the smoke is prevented from entering the box. It is probably due to the vortex motion of the air rushing in to fill the vacuum, for it has been calculated that there is a vacuum just at the base at these velocities. During this process the air is heated and great changes in density take

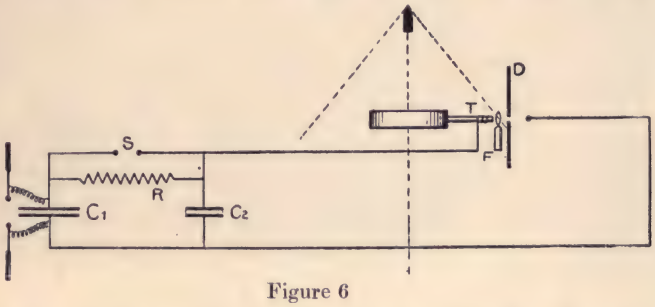

Figure 6

place. These eddies broaden out considerably within the limits of the picture.

The apparatus previously described is expensive and difficult to obtain; similar results, not so perfect in detail, may be secured as follows. Fig. 8 was taken without a camera and with commercial dry plates. It is a special bullet, 0″.300 caliber, velocity 2,100 feet per second. There is a hole through it axially and a copper disk was fitted to the base to prevent the powder blowing out through the hole. This disk is seen at the rear with its own head and tail waves and eddies. At the rear of the bullet is seen an unexpected set of waves showing that the air at that velocity does not flow through freely. Thus the bullet has as much resistance as a flat headed one and

Figure 7

much less energy to overcome it as it has a smaller mass.

This photograph was taken with the apparatus shown in Fig. 9. B is a light tight box, hooded at the ends to prevent light through bullet holes from falling on the plate. S is the spark gap and w w the wires short-circuited by the bullet. The circuit is given in Fig. 10, and is due to C. V. Boys, of London. The lettering corresponds to that in previous diagrams. S' is an additional gap, enclosed, so that C_1 has to discharge through two gaps in series. The condensers are charged to the desired potential which is less than that required to jump both gaps in series. If one gap, S', can be short-circuited then C_1 will discharge through S, the photographing gap. This is accomplished by a secondary circuit through S', C_2 and G. When G is closed by the bullet, C_2 discharges through S' and hence C_1 through S. This is a "shadow method"; Fig. 2 is an example.

The preceding methods of showing air waves are surely refraction phenomena, as may be seen from Fig. 11. Let O be a point source of light—an electric spark —and PP a photographic plate. A section of the wave perpendicular to the axis would be represented by two circles. Light falling to K is unchanged in direction but a ray striking a region of greater density is deflected toward the normal on entering and away from it on leaving so that such a ray would take the course

Figure 8

OM. Otherwise it would have arrived at R', so that there is an absence of light at M' and a cumulation at M.

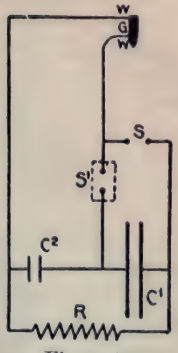

Figure 10

One is led to ask if application cannot be made to the useful arts and sciences, or in research or invention, of these powerful methods of analysis. In the case of the bullets, for instance, a movement of 1/100″ during exposure would show a blur on the negative. At 2,700 feet per second the time of exposure must be less than $\frac{1}{2700 \times 12 \times 100} = \frac{1}{3{,}240{,}000}$ second. Hence a study of phenomena at high velocity might find application of these methods. These may be studied "point by point," using large negatives and thus securing fine detail. In fact, the method of Fig. 9 gives enlargement; the writer has used it up to three diameters with success. It seems applicable to work on air or gases where the index of refraction can be utilized, and to a lesser degree, in liquids or crystals. A sound wave traveling longitudinally through a glass rod has been photographed velocity, 5,000 feet per second. A consideration of Fig. 11 shows that a point source of light is necessary; otherwise the well defined shadows will not be obtained. The range of the methods is surprising. The writer has used the scheme of Fig. 10 with great success with 20 feet between spark and plate. In this case the gaps were about 3/4″ long each and Cramer Crown and Hammer slow

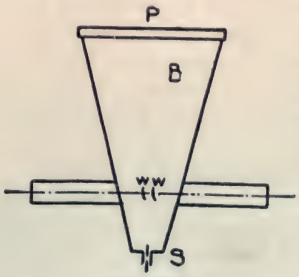

Figure 9

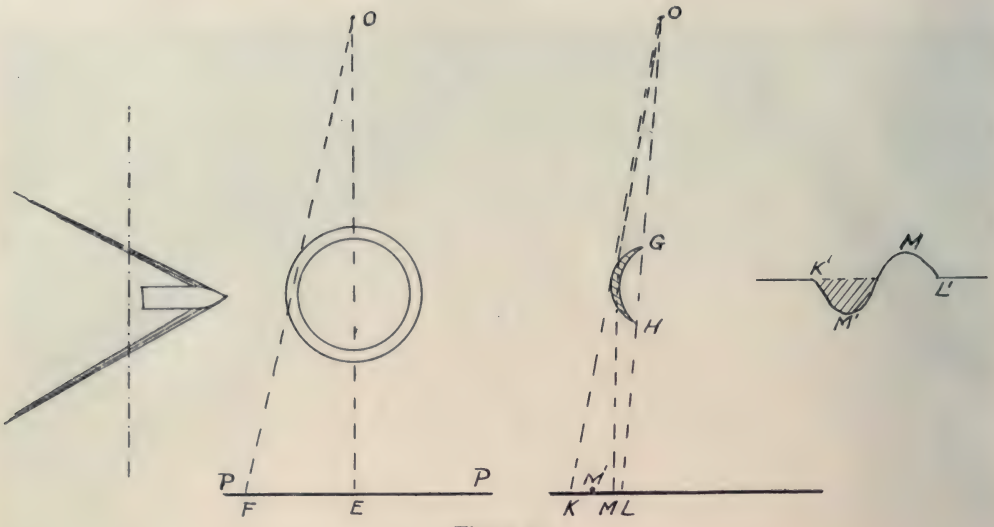

Figure 11

plates were used, 10 years old. The spark looked to be one half inch in diameter, but this is a physiological phenomenon as the pictures showed it to be virtually a point. One marvels that so much light can be concentrated in a point during so short an interval of time yet have enough actinic value to properly expose a photographic plate 20 feet away.

It is suggested that the formation and growth of crystals is a field where these methods might be applied with advantage. Theories regarding the birth of a crystal need confirmation; some of them have a bearing on the constitution of matter.

Nothing has been said about applying these ideas to a moving film; a great field is opened when apparatus is developed to do this conveniently. Bullets have been photographed at the rate of 92,200 per second, but little application has been made of the method in the arts. One would expect to get new ideas by using these methods stereoscopically, examining the pictures with a stereoscope and thus obtain space relations which cannot be gotten from single pictures.

The writer will be glad to coöperate with those desiring to make use of these ideas in the arts, feeling that such work would be truly constructive.

BEGINNINGS OF PHOTOGRAPHY

It is said that the action of light on fused silver chloride was used to make a photograph of the solar-spectrum by Scheele in 1777.

The first successful inquirer to secure permanent pictures through the influence of the sun's rays, seems to have been Nicephore Niepce, who in 1824 effected the progress of heliography by the use of a varnish made of asphaltum, or bitumen of Judea, applied to a highly polished metal plate or a glass plate, and developed by essential oil of lavender and white petroleum. The plate was exposed for several hours, the image etched, and then prints were made as from an ordinary etching.

The daguerreotype process consisted of exposing a polished silvered copper plate, fumed with iodine, in a camera a few minutes, developing the exposed plate with mercury vapor and fixing the image with hyposulphite. This complex process involved five distinct operations: cleaning and polishing the plate, coating the plate with sensitive ioduret of silver, adjusting and exposing the plate in the camera obscura, developing the invisible picture after the exposure, and removing the sensitive coating.